MECHANICAL ENGINEERING

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

September 1928


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Mechanical Engineering

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CONTENTS OF THIS ISSUE

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Eugene McAuliffe

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L. W. Maxwell

Contributors to This Issue

Eugene McAuliffe, president of the Union Pacific Coal Co. and Washington Coal Co., Omaha, Neb., was born and educated in Kent, England. He started his professional career in 1886 by serving a shop apprenticeship with the Northern Pacific Railway and later was transferred to locomotive service. As locomotive engineer and in related capacities he was employed on various roads in this country and Mexico.

Mr. McAuliffe organized the International Railway Fuel Association in 1908 and was its president for two years. During the years 1908 to 1910 he was president of the Brazil Block Coal Co. Later he was appointed general coal agent of the Frisco Lines, resigning in 1917 to enter the service of the North American Co., operating public utilities. From 1918 to 1920, in connection with his other duties, he also served as manager of the fuel-conservation section, division of operation, U. S. Railroad Administration. He was elected to his present position in 1923, at the same time being appointed special representative of the President of the Union Pacific System. He has received the honorary degree of Doctor of Engineering from the School of Mines and Metallurgy, University of Missouri, "for distinguished engineering and executive service in the mining and distribution of that essential commodity of modern civilization, coal."

A. C. Butterworth, electrical engineer with Picklands, Mather & Co., Duluth, Minn., was graduated in 1911 from the University of Minnesota with the degree of E.E. After a year and a half in the operating and engineering departments of the St. Paul Gas Light Co., he entered the engineering departments of the Oliver Iron Mining Co., Duluth, Minn., where he was located for seven years. Previous to his present position, Mr. Butterworth was associated as mechanical-electrical engineer with the Montreal Mining Co., Hurley, Wis.

Anton Tancig, mechanical superintendent of the Shenango Furnace Co., Chisholm, Minn., has taken an active part in developing improved methods for mechanizing the mining industry.

W. A. Shoudy, associate professor of mechanical engineering at Columbia University, and consulting engineer, New York City, was graduated from Stevens Institute of Technology in 1899, later serving on the faculty as assistant professor of engineering practice. During his professional career Mr. Shoudy has been associated with the Edison Electric Illuminating Co., as engineer of tests; with the J. G. White Engineering Corporation, as assistant mechanical engineer; with the American Sugar Refining Co., as power engineer; and with the Adirondack Power & Light Co. as superintendent of steam stations. He is a member of the Publications Committee of the A.S.M.E. and the Prime Movers Committee of the N.E.L.A.

William Jacobi is manager of the Keokuk Steel Castings Co., Keokuk, Iowa, a subsidiary of the Springfield Boiler Co. Although his early experience was with the development of electric motors with the Crocker-Wheeler Co., he has for many years been actually engaged in combustion and boiler problems, first in the development of oil furnaces for industrial purposes and later with the J. G. White Engineering Corporation in steam-power station design. He later joined the engineering department of the Springfield Boiler Co. and was transferred from there to his present position.

F. L. Bishop, professor of physics at the University of Pittsburgh since 1909, is dean of the School of Engineering and the School of Mines. He acts also in a consulting capacity for the American Window Glass Co., and the Window Glass Machine Co. He is editor of *Engineering Education* and secretary of the Society for the Promotion of Engineering Education. Dr. Bishop was graduated in 1898 from Massachusetts Institute of Technology with the degree of B.S., receiving his Ph. D. from the University of Chicago in 1905.

A. H. Marshall, for the past year experimental test engineer for the Pratt & Whitney Aircraft Co., Hartford, Conn., attended Princeton University, where he received the degree of B.S. in engineering in 1926 and his M.E. in 1927. The paper appearing in this issue by Mr. Marshall is an abridgment of his graduating thesis for the latter degree. He received also one of the two A.S.M.E. Student Prizes for 1927.

L. W. Maxwell, consulting economist and statistician in New York City, was formerly associated with Harrison S. Colburn in factory location work around and along the New York waterfront. He was at one time engaged in plant-location activities in the Middle West and also located as investigator for the National Industrial Conference Board. Mr. Maxwell is at present employed in investment advisory and editorial service. He is the author of several books and bulletins on economic subjects, and is an extension lecturer in New York University. He holds the degrees of A.B., A.M., and LL.M.

This Month's Cover shows a modern method of mining coal. It is symbolic of the mechanical engineer's contributions to the art of mining which are described in this issue in a series of three papers on mine mechanization. The picture itself is published through the courtesy of the Sullivan Machinery Co., and shows one of their cutting machines drilling the face, after undercutting, in a mine at Columbia, Utah.

MECHANICAL ENGINEERING

Volume 50 September, 1928 No. 9

Mechanical Engineering in Coal Mines

Substitution of Electricity for Steam and Mule Power—Factors in the Coal-Loading Problem—Resistance of Mine Labor to Innovations—Growing Value and Importance of The Mechanical Engineer in the Coal-Mining Field

By EUGENE McAULIFFE,[1] OMAHA, NEB.

DOUBTLESS the earliest engineering service rendered the mining industry was that of establishing locations for mine openings and thereafter directing the course of the underground adits, a crude magnetic compass being used in certain instances to point the way and a wooden pole being employed as a measuring instrument. Years passed, and then came the discovery of the steam engine, a mechanical device which was first used to pump water from British coal pits; and thereafter the first real task given to the puny locomotive of the day was that of hauling coal from a British mine.

For three-fourths of a century after the adaptation of steam to coal-mine usage, the work of the mechanical engineer was largely absorbed in the development of steam-driven water pumps, winding engines, etc. In the last quarter of the nineteenth century the demand for a successful coal-cutting machine appeared and air-driven coal-cutting machines of the punching or percussion type were developed, relieving the miner of the arduous task of cutting a wedge-shaped groove in the coal just above the floor or in the floor material underlying the coal seam. This machine did valiant service in certain low coal districts and where the coal was too hard to cut successfully with the miner's pick; and with added modifications, the punching machine was also used to shear the coal seam vertically. The difficulties that attach to the use of compressed air within mines and the limited capacity of the punching machine were solved by the invention of the electric-driven chain coal-cutting machine, a device now in general use, fully 72 per cent of the bituminous coal of the United States being undercut by machines in 1926.

Electricity for Steam and Mule Power

The introduction of the coal-cutting machine led to a more general substitution of electric for steam power in the operation of pumps, and the shift from the pit mule to the electric mine locomotive quickly followed. In the development of the mine equipment referred to, as well as in the boiler room, in the power house, and in the tipple, the mechanical engineer had rendered signal service, but his great task yet lays before him in supplying power-driven coal-loading machines for the work of lifting coal by hand from the floor of the working place into the pit car. The magnitude of the task that attaches to loading into mine cars the nation's annual production of coal will be readily comprehended when it is understood that the cubic-yard content of 562,000,000 tons of soft coal, a volume approximating the hand-shoveled output for one year, would cover an area of one square mile to a depth of 800 ft., a pile equal to 272 times the cubical capacity of the Great Pyramid of Cheops.

The power-driven coal-loading machine was definitely developed by W. A. Hamilton in 1907. The original Hamilton coal loader made a substantial start toward success, loading 150 tons in one eight-hour shift, but the mine labor employed by the coal company in whose mine the experiment was being conducted struck against its use, and after many vicissitudes the inventor gave up the struggle. Little was done until 1922, when a machine not remote in design from the original Hamilton appeared, giving the task new life and new impetus. Today there is a loader capable of successful use under every condition of mining, and each year brings out new ideas, new machines, and new methods; and while the percentage of coal mechanically loaded is yet small, the ratio in which the work is expanding, as shown by the following figures, is definitely encouraging:

	1923	1924	1925	1926
Number of mines using loading machines..........	60	83	95	131
Number of machines used............	125	219	340	455
Net tons loaded by machines.........	1,879,726	3,495,522	6,243,104	10,022,195

While the figures for 1927 are not yet available, it is reasonable to estimate the quantity loaded by machines for last year at from 13,000,000 to 14,000,000 tons.

Many Types of Coal Loaders Now

There are many types of coal-loading machines—too many, in fact, to attempt within the brief space available the task of describing them. Certain machines were designed as loaders only, while others are of the composite type, coupling for example the work of undercutting the coal with its loading. Again, other devices serve to join the work of loading with that of mine transport. Many elements foreign to the above-ground experiences of the engineer must be taken into account in the design and adaptation of any underground device; space limitations, coal seams which pitch heavily, the roof supports required, and that most important element, adequate ventilation, all are compelling factors. Engineers who have labored with the difficult problem of ore reduction, including the handling of rocks grading from the softest up to the hardest, will find quite the same degree of variation between coals. The character of the coal in place, including its natural cleavage lines, or, as sometimes happens, the entire absence of them, affects the work of the mechanical loader.

After more than five years' active connection with the work

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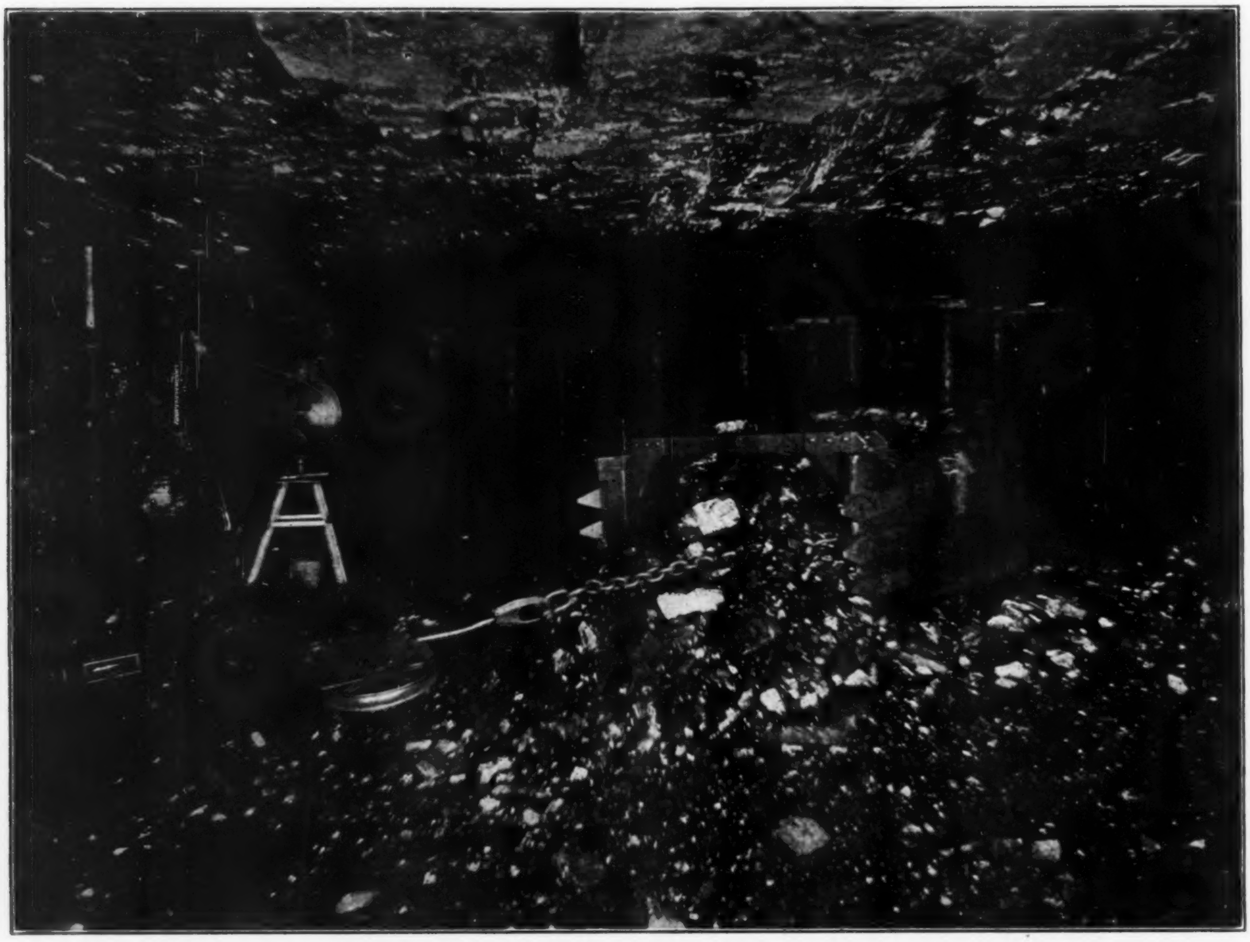

Goodman Scraper Loader, Showing Automatic Sheave, No. 8 Mine at Rock Springs, Wyoming

Universal Shaker Loader and "Duckbill" Loading in Room 22 x 300 Ft.

Joy Coal Loading Machine, Union Pacific Coal Co., Mine No. 4, Hanna, Wyoming

of mechanical coal loading, the author is prone to repeat that the greatest engineering task confronting the manufacturer of coal-loading machinery is the human one. The designing engineer has done valiant work, and the men who sell the machines have proved fervent evangelists, but the "coal mind" moves slowly, and the manufacturer who undertakes to underwrite more than the general design and quality of the material used in his machine is facing trouble. A salesman cannot always sell the proper attitude of mind to the buyer with his machine, and it is no exaggeration to say that coal-loading success is mine-management success. The mine manager who succeeds in a mechanical coal-loading program is the man who makes up his mind to succeed

Sullivan Machinery Co.'s Track Cutter in Position for Undercutting at the State Mine, Boulder Valley Coal Co., Erie, Col.

in spite of all difficulties; labor opposition, unforeseen obstacles, even weakness of machine design. The engineer and manufacturer can modify or eliminate weakness of design or material where he cannot reform mine management. This portion of the task rests with the management itself, and in "management" is included every one from the apprentice to the president.

Resistance to Innovations

The opposition of mine labor to new methods has its foundation sunk deep in more than a hundred years of mining tradition. This opposition to change is too often quite as deeply fixed in the mind of the manager as it is in that of the workman. The coal loader has been held back by the indisposition to change from the method of development established to meet hand-loading conditions. For example, certain states found it necessary to restrict the use of explosives within the mines to off-shift hours. In the light of the conditions that obtained when the laws were passed, this action represented a step forward. In Kansas, for example, all coal is shot from the solid with black powder; and blown-out shots, with incipient mine explosions, are numerous. The population of certain small Kansas graveyards is said to consist mainly of shot firers. With the principal working force out of the mine, the shot firers may legally kill themselves for $12 to $30 a shift. In certain other states quite the same laws govern, and coal may be shot in any manner, with any explosive, during off-shift hours, although shooting is definitely forbidden with the main force below; and so mechanical loading is retarded. The state should prescribe safe methods, safety explosives, rules of

10-Hp. Slushing Hoist Used With Slide for Main-Level Work

procedure, and thereafter enforce the rules. Great Britain, France, and Belgium have real mining laws and real enforcement, with the result that their combined average mine-fatality rate, when measured in terms of million man-hours of exposure, is but 21.8 per cent of ours. It is this mongrel mixture of state mining laws, plus an absence of mine-safety conscience, coupled with the fact that the task of state mine inspector is looked upon as a job

to be given in return for party activity, that is largely responsible for the present unenviable record. The workers who make up the union constituency are quite as indifferent to the unfortunate mine-safety situation as are the owners, although they supply the lives and limbs that are used in the sacrifice. Fifty per cent of the state mining regulations are honored in the breach rather than in the observance. As in the case of the present coal-mine labor situation, the public is, with the exception of a few politically minded legislators and a lesser number of social workers, paying little attention to the mine-safety problem.

Mechanical Engineer to Have Greater Part

In conclusion, it is the author's belief that the further mechanization of coal mines will continue and that the mechanical engineer will grow in value and importance in the coal-mining world. Again, time and space prevent any attempt to forecast the changes that will certainly occur in the art of mining coal. Through further mechanization processes, workmen now paid for creating foot-pounds of energy will become the builders, operators, and maintainers of machines. The cost of production will be lowered, and methods of mining will be changed to provide for the more prompt removal of the mineral within a given area, with less reserve mineral lost. This calls for concentration of the working area, and this in turn will make for more efficient ventilation and fewer disastrous explosions. Mines in which a number of men work together within a comfortable area will admit of better supervision, more efficient illumination, and the assignment of specially trained men to the use of explosives and machinery. Electric service lines and apparatus will be employed in volume and under conditions such as not only to justify but to require the services of competent electrical engineers. With the items of interest, taxes, depreciation, and obsolescence, as well as the cost of ventilation and pumping, running as constants against the cost of production, the industry will eventually, like the public utilities, look to multiple shifting as a means toward obtaining a better load factor. Few operators realize that 175 working days, a common yearly average for coal mines, supply a load factor (holidays excluded) of less than 20 per cent. We cannot have too much of the far-seeing mechanical engineer in the coal industry.

Use of Electric Power in Iron Mining

Its Development in the Lake Superior District and Effect on Ore Output—Possibilities of Further Applications—Equipment for Successful Operation

By A. C. Butterworth,[1] Duluth, Minn.

The growth of the use of electric power in the iron-mining industry of the Lake Superior region has been so gradual and unobtrusive that those who are directly in touch with the work fail to realize at times the tremendous importance that electricity bears to the industry as a whole.

Probably the earliest use to be made of electric power was in running small motors and in furnishing lights on the surface, but it was soon extended underground for the operation of electric locomotives. In the Lake Superior district 250-volt direct current became standard, and it has remained as the standard for underground haulage work. Since steam was the primary source of power at practically all mines, steam-engine generators were largely used during the earlier years. The advantages of electric haulage over hand tramming became so evident that this stage in the development went ahead rapidly. In the meantime small pumps had been connected to motors, and the application of motor drive to small hoists and compressors was undergoing development.

Some few mining properties were fortunately situated, so far as water power was concerned, and carried on considerable experimental work in the development of motor applications. Other properties found their electrical loads increasing beyond the capacities of generating plants and faced the alternatives of increasing generator capacities or purchasing power from local power plants. The latter choice was frequently the cause of much trouble owing to the inadequacy of the lines and equipment of the early power companies, and in spite of continued betterments and improved service it has been only in recent years that the mine operators have felt secure without a steam auxiliary to fall back on in case the electric power were to fail them.

Growth of Use of Electric Power

Probably the first iron mine in this district to be completely electrified was the Penn mine at Vulcan, Mich., electrification of which was started in 1906. In 1910 the Cleveland Cliffs Iron Company started extensive electrification of its properties in and around Ishpeming, Mich. In 1912 the Davidson and Bengal mines at Iron River were completely electrified, these being the first mines to operate entirely on purchased power. In 1913 the Oliver Iron Mining Company built a hydroelectric plant at Quinnesec Falls on the Menominee River below Iron Mountain, Mich., for furnishing power for the operation of a set of 3000-gal. centrifugal deep-mine pumps in its Chapin mine. The development of the Peninsular Power Company in the Menominee Range district of Michigan was responsible to a considerable extent for the early electrification of the mines in that territory, but electrification of mines in other districts did not lag far behind. In 1910 there probably was not a mine in operation that did not make some use of electric power, although there were very few motor-driven hoists and compressors and not very many motor-driven pumps. The next ten years saw a complete reversal of conditions, so that after the slump of 1921, with very few exceptions, the underground mines that resumed operations either had already been completely electrified or were in process of being changed over to electric drive.

The use of electric power in the past five years has continued to show an increase which appears to be reflected directly in increased efficiency. In 1922 a group of twelve representative underground mines, nine of which were completely electrified and the others partially electrified, showed a power consumption of slightly less than 4 kw-hr. per ton. In 1927 a similar group of

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sixteen mines showed a power consumption of slightly over 8 kw-hr. per ton.

Although the use of electric power cannot be credited with the entire increase in efficiency, it is interesting to note that coincident with the foregoing increase in power consumption from 4 kw-hr. to 8 kw-hr. per ton the mining efficiency as expressed in tons per man has nearly doubled in the same length of time.

Electric Power in Underground Mining

The uses of electric power in underground mining include the following operations: hoisting (skips and cages), air compressing, pumping, underground and surface haulage, ventilation, "slushing" or scraping dirt, crushing, lighting. In addition, there are surface uses such as shop power, crushers, sample-drying ovens and laboratory equipment, miscellaneous surface power and lights, as well as operation of mine signal systems and a certain amount of electric blasting.

Of these uses the consumption due to pumping is largely independent of mining operations except as the increased depth of a mine will increase the head and sometimes the amount of water flowing. The consumption due to hoisting, assuming normal operation with good equipment, is almost directly a function of the production and depth of hoisting. For the year 1927 the pumping power for the previously mentioned group of electrically equipped mines amounted to about 40 per cent of the total power consumption; or in other words, for every ton of ore produced, $2^1/_2$ tons of water were pumped a vertical distance of 1000 ft. The sum of the hoisting and pumping power amounted to approximately 50 per cent of the total power. The work performed by these two operations is not subject to variations except as to production, depth, and amount of water, and would normally have no effect on the mining efficiency. It is in the intelligent use of the remainder of these items that the mining efficiency can be increased.

The power used in compressing air is, next to pumping, the largest single item in this list and amounts to approximately 35 per cent of the total power. Compressing air by electricity is one of the most expensive ways of using power, unless constant attention is paid to the matter of leaks, proper sizes of air lines, and the question of overtime operation. We have found that for individual mines the power consumption per ton varies from about 1.5 kw-hr. to approximately 10 kw-hr., depending on the extent of the air-distribution system, the number of hours during the month in which the compressor is running, the condition of underground ventilation, the type of mining equipment and method of mining being used, and to a certain degree the character of the material being mined. Adequate air pressure at the working places underground is a prime requisite for satisfactory mining efficiency, and no effort should be spared in making this condition possible. However, it is frequently found that increased compressor capacity increases power costs owing to additional use and waste of air without a corresponding increase in efficiency; and the tendency now is to reduce the use of air as much as possible by substituting other methods of operation.

Wasteful Practice of the Old Days

In the days of the steam compressor, the engineer used to cut back the governor or throttle down the engine during noon hour and between shifts, and the miners would leave their valves open to blow out the smoke after blasting. This was generally accepted as good practice, and the amount of air thus used was not sufficient to affect the coal pile to any great extent, especially since use was made of the compressor exhaust steam in heating buildings and for the feedwater heaters. With the modern air compressor, however, the motor runs at constant speed, and the governor tends to maintain a constant high pressure, so that practically the full capacity of the machine would be required for similar service under present conditions.

Partly on account of this fact, and partly because of a growing consciousness of the average unsatisfactory air conditions underground, more and more attention is being paid to the question of mechanical ventilation of the mines. There is not the necessity of getting rid of explosive gases which exists in some coal mines, but the heat and the carbon dioxide due to decaying timber matting, together with the powder smoke underground, make it necessary to pay attention to this problem. In the early days many mines had reasonably good natural ventilation, but with the increased depth of mining even those mines are now turning to mechanical ventilation. Many devices have been tried out to improve local ventilation in exceptionally poor places. Direct blowing of compressed air and the use of air "injectors" and air-operated fans and blowers have generally given way to the use of the latest type of portable motor-driven ventilating fans. The trend of this work, however, is toward the large mine-ventilating unit, together with a proper system of air doors throughout the mine, to give adequate and positive ventilation everywhere in the mine. At some mines it is found necessary to operate these big fans only occasionally, but sometimes conditions make it necessary to run them continuously; and without question, considerably more power can be used to good advantage for this purpose in most underground mines in this territory. Although no comparative figures are available, it stands to reason that fresh air will keep the mining efficiency higher than if the air were hot and "dead," as is frequently the case at present. At one property operated by Pickands, Mather & Co., where the fan is used continuously, the power consumption is about 1 kw-hr. per ton; and, as expressed by the underground men, "this fan is worth a million dollars."

Slushing Hoists a Great Improvement

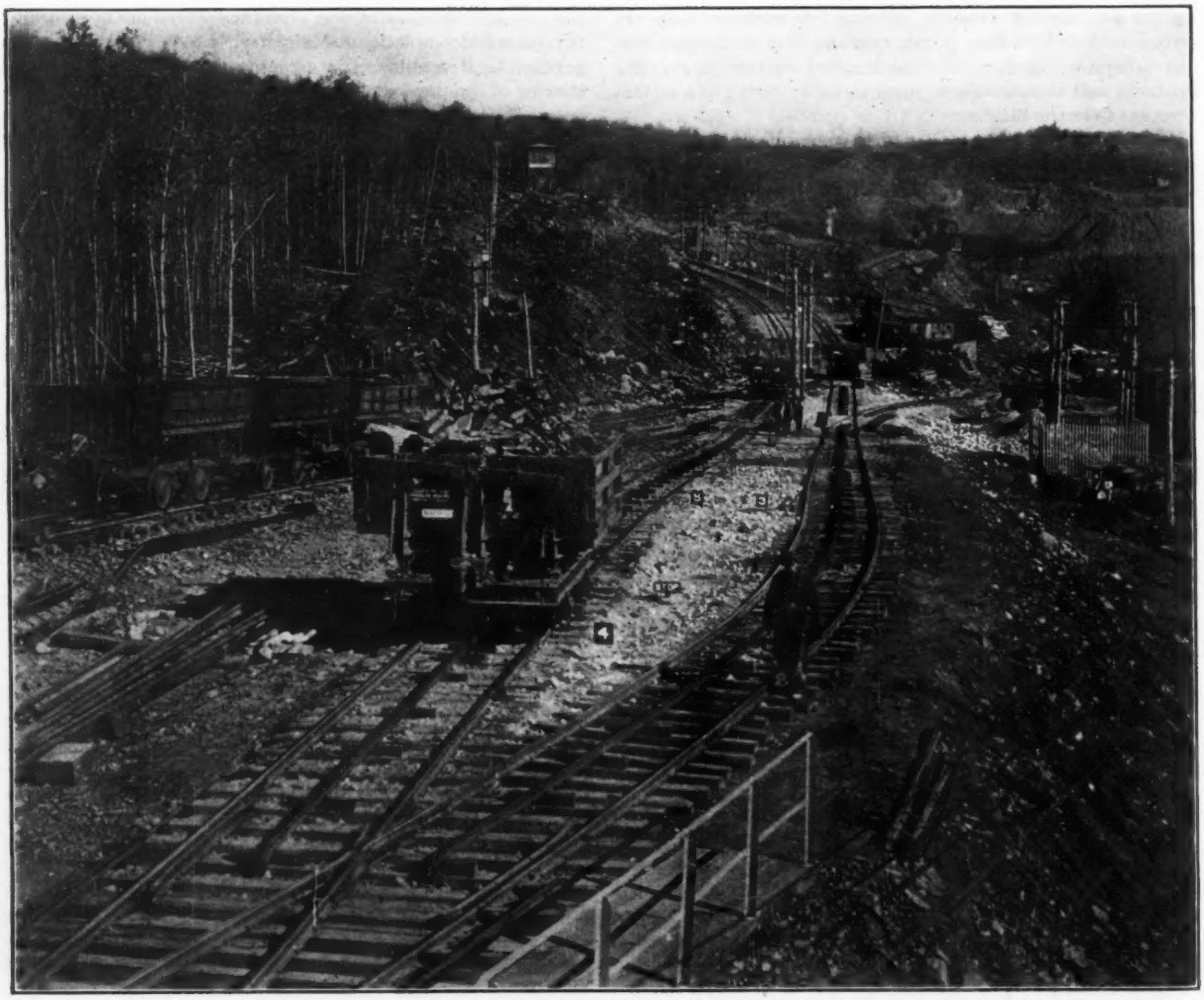
Probably the factor of greatest importance in the last six years in increasing the mining efficiency has been the development of the slushing hoist and its adaptation to the problems of mining. The earliest equipment probably consisted of a small steam-operated hoist pulling a scraper such as was formerly commonly used in general excavating work on the surface. From this beginning the equipment has been developed successively through refinements of the air engine and final application of electric drive, so that now practically all underground mines have slushing hoists of some type or other operated either by air engines or electric motors. There are several double-drum hoists in operation, driven by 25-hp. motors, and capable of handling scrapers more than 4 ft. wide at a rope speed of approximately 300 ft. per min. Such an outfit with two-man crews working on 8-hour shifts recently mined and scraped into the loading chute more than 1000 tons of ore in one 24-hour period, and for the entire month in which this record was made this one machine was credited with about one-third of the total production from this mine. There are a number of hoists of this size and slightly larger in use in the open stopes or in handling dirt to transfer "raises" in several of the mines, but the largest part of the tonnage from slushers is produced with smaller outfits of from $6^1/_2$ to 10 hp. capacity, handling scrapers from 24 to 36 in. wide. Most of the electric slushing hoists are equipped with 250-volt direct-current motors, and in the smaller sizes are thrown directly across the line in starting. There are several scattered hoists that are equipped with alternating-current motors, either 220 or 440 volts, and the Oliver Iron Mining Co. has laid out and is equipping its Godfrey mine, one of the large underground mines on the Mesaba Range for 440-volt alternating-current slusher operation throughout. What this equipment has meant to mining may be best illus-

trated by saying that the quantity of No. 2 round-point shovels purchased in 1927 was probably less than one-fourth the number purchased during a similar year before the development of slushing.

Lighting and Other Uses

The use of electricity for lighting underground was an early development which probably has not been expanded to its logical limits. Notwithstanding several bright and shining exceptions, the majority of mines are not illuminated to the degree that is economically feasible. Although no direct comparisons are possible, there is a growing feeling that underground illumination can be very materially increased to the advantage of mining efficiency, and that it will also assist in eliminating accidents underground. At one underground mine the power consumption for lighting amounts to over 1 kw-hr. per ton, and this expenditure is considered a good investment by the mine organization. At another mine recently a light at a raise was credited with saving the lives of two men caught in a blasting accident.

The time has passed when electrification of any property can show an extraordinary saving over existing steam operation. Of the mines which were operated by small, inefficient boiler plants ten years or more ago, virtually all have been either changed over to electric power or have closed down on account of depletion of reserves or from economic pressure. The existing boiler plants which furnish steam directly for hoisting, compressing, pumping, etc., are operated at a high degree of efficiency, due regard being paid to the questions of heat balance, labor-saving equipment, and general all-around economy. Surveys made of these properties generally show that electric operation would result in an actual saving in operating cost, but not enough to justify scrapping the existing equipment unless the element of obsolescence or inadequacy enters into the question. It is anticipated that eventually even these plants will be superseded by electric power as the mines increase in depth and it becomes necessary to purchase new equipment. Taking all of these factors into consideration, it seems as though there might be a continued growth in the use of electric power in underground mines up to at least 12 kw-hr. per ton of production, or 50 per cent more power than at present. The figures given have been worked up from the records of mines operated by Pickands, Mather & Co., and it is believed that they are fairly representative of average conditions which obtain throughout the Lake Superior district.



General View of Approach to Pit Showing Track Layout for Woodford Haulage System

Electric Power in Open-Pit Mining

The preceding paragraphs have considered the use of power only in underground mining. The larger part of the annual tonnage of iron ore comes from the open-pit mines on the Mesaba Range, and the use of power in these open-pit mines presents different problems. Open-pit mining is essentially a material-handling and railroading job, with the introduction of special problems such as grading, boat schedules, etc. Practically all the open-pit mines have been stripped of their overburden by means of steam shovels and steam locomotives, and a large proportion of the present annual ore tonnage is handled by the same means. However, a few of the recent stripping jobs have been done partly by electric power, either with electric shovels or drag lines, or by hydraulic sluicing. In practically all cases, however, the haulage is by steam locomotives.

The use of electric power for shovel operation in the regular production of ore is becoming more and more general, although it will probably be a long time before the steam shovel will become obsolete on the Mesaba Range. Electric shovels in operation range in size from the small $1^3/_4$-yd. revolving shovel up to the 350-ton revolving shovel on trucks, using a 10-yd. dipper. Some earlier shovels are equipped with a-c. motors, but the latest ones use a synchronous or induction motor-generator set, with d-c. motors and Ward Leonard control.

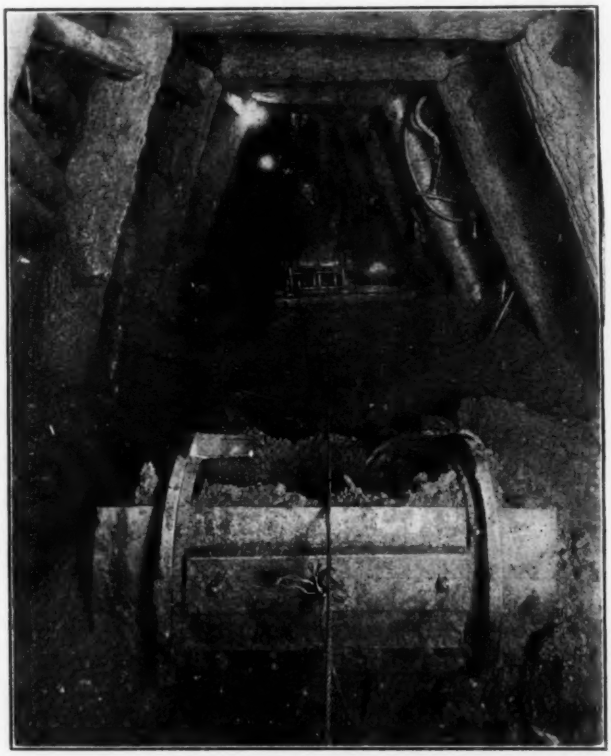
The first open-pit mine to be completely electrified on the Mesaba Range, and up to the present the only operating mine on this range so equipped, was the Wabigon mine at Buhl, Minn., operated by M. A. Hanna & Co., which was electrified in 1924. The new Missabe Chief mine at Keewatin, Minn., operated by the same organization, is also now being equipped for complete electric operation. The haulage at both of these mines is by means of trolley-type electric locomotives weighing about 60 tons and operating on 600 volts direct current.

The Volunteer mine at Palmer, Mich., operated by Pickands, Mather & Co., which shipped its first ore in 1926, is at present the only other open-pit mine in the Lake Superior district operated entirely by electric power. The haulage at this mine is by means of the "Woodford system," which has been used at a number of places in quarry work but never before used in open-pit iron mining. In this system each car is equipped with motors operated on 250 volts direct current and running on standard-gage tracks with a third rail. The third rail is sectionalized and energized by feeder cables from a central control tower located where the tower man can have a good view of the pit. The cars are equipped with selector switches so that the operator can apply power or brakes in varying degrees by changing the voltage on each section of track. The cars are equipped for dynamic braking when going down grade, so that even if power should fail, the cars are automatically limited to a safe maximum speed. At reversing points along the track, track cams are installed which throw over the reversing-switch equipment on each car as it comes along, thus obtaining the proper direction and sequence of operations. At this particular mine all the ore goes through crushers, and there is no occasion for the regular railroad cars to go into the pit. If such were not the case, this particular type of haulage could not have been used. With this system the only haulage operating labor consists of one man in the central control tower, one man on the shovel for spotting cars for loading, and one man in the crushing plant for spotting and dumping the loads into the crusher.

More and more each year the product from the iron mines is being treated or concentrated in some way before shipment, either to get a more uniform and sizable product or to improve the analysis by the elimination of objectionable elements such as silica. This treatment may consist of screening, crushing, washing, or drying, or of any combination of these operations. There is no question that electric power is the most adaptable and economical for this work; and with the depletion of high-grade ores and the increasing necessity for concentration of low-grade ores, the use of electric power for this purpose is without question going to increase as time goes on.

Future Possibilities in Open-Pit Mining

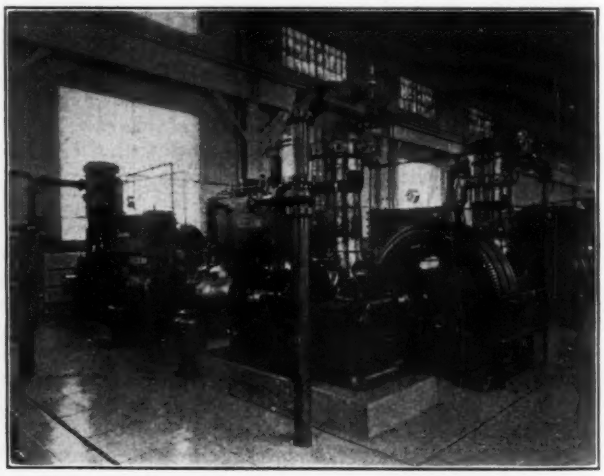
The present consumption of electric power in open-pit mining, which amounts to about $1^1/_2$ kw-hr. per ton, is largely used in pit drainage and the operation of electric shovels and plants for benefication of ore, with the occasional use of motor-driven compressors for furnishing air for drilling in the pit. Most of the drilling is done by churn drills, and the power consumption per ton is relatively light. Power is also used for the operation of shops, for lighting locations and mine buildings, for the operation of laboratory equipment, and for other miscellaneous purposes. Considering the possibilities of complete electrification of haulage and digging operations and the probable increase in concentrating plants, a reasonable outside figure for the use of power in open-pit mining would be 5 kw-hr. per ton. This consumption will probably not be reached for a considerable period of time, however, partly because the Mesaba Range as a whole has adequate steam equipment which it would not pay to scrap, and partly because the present rate structure of the company furnishing power in this district unduly penalizes the mine operators for the irregular character of their operations. Production from open-pit mines is necessarily limited to six months in the year, and during that time the operation of any individual mine is frequently very irregular, depending on the naming of boats for cargoes. Closer cooperation between the mines and the ore agents at the lower lake ports may help this situation to a certain extent, but so long as there are fogs and bad weather on the lakes there will always be times when boat



25-Hp. Slushing Hoist Scraping to a Raise in Sub-Level Work

A 350-Ton, 8-Cu. Yard Capacity Steam Shovel, Loading Iron Ore Into Cars for Shipment to Lake Docks at Duluth

Double-Drum Motor-Driven Cage and Skip Hoists



Motor-Driven Air Compressors

traffic is tied up at one end or the other, and consequently there will always be days when all the equipment is producing at full speed and other days when not a wheel is turning.

No mention has been made of the process of producing sponge iron directly from iron ore in this district, experimental work on which has been carried on over a considerable period by the University of Minnesota School of Mines. This is not directly an iron-mining problem, although it may affect the use of power in mining operations, but it does open the door for a consideration of possible uses of power for this purpose.

Necessary Characteristics of Equipment

Iron mining is essentially a destructive game. For this reason, the point of view of the miner who is handling electrical equipment is necessarily different from that of a man who may be engaged in building up rather than tearing down. It should be evident, therefore, that any electrical equipment used in mining, such as locomotives, slushers, shovel equipment, etc., and all control equipment handled by the producing labor at the mines should be as sturdy, compact, simple, and as foolproof as possible. It is easy enough to sit in an office and say that the men should use a reasonable amount of care and common sense in handling such equipment, but the fact remains that this equipment is provided to enable the men to get out the dirt; and if it is complicated, or hard to handle, or cannot stand rough and heavy service, frequently under extremely wet and dirty conditions, the equipment is not suitable and does not remain long in service. Equipment which is satisfactory for ordinary industrial use is frequently entirely unsuited for mine purposes, and the present tendency is toward the development of an exceptionally rugged line of equipment with control apparatus as simple as possible. The success of further extensions in the use of electric power, either to increase the mining efficiency or to decrease operating hazards, will depend to a considerable extent on whether satisfactory equipment can be provided and operated at a cost which will let it compete with present methods of mining.

Mechanical Engineering in Iron-Ore Industry

Modernization of Mines on the Iron Range of Minnesota, With Their Almost Complete Mechanization, Credited to the Ability of the Profession in Solving Complex Problems as Operation Developed

By A. TANCIG,[1] CHISHOLM, MINN.

MECHANICAL engineering in the iron-ore industry of Minnesota had its beginning in the early days of iron mining, when mining was a crude, hand-worked operation that was improved and made more efficient through the gradual introduction of mechanical methods and machines, until at the present time, after a growth of 40 years, we find hand labor of minor importance in the production of iron ore, practically all of the operations being carried on by mechanical appliances. This same growth in improving methods changed the status of mechanical engineering in the industry from the simplest kind of work to engineering embodying complexities met with in but few other industries.

In order for one better to visualize the growth and importance of mechanical engineering in iron mining in Minnesota, the salient historical points will be reviewed. The gradual progress will be traced, to the end that not only will the necessity of mechanization of the mine be self-evident, but that the pioneer engineers will be given full credit for supplying a fertile background for the present, with the resultant increasing production and lower costs.

The early mining of iron ore in Minnesota was entirely a hand operation—hand-shovels, hand-drills, wheelbarrows—with all the ore being raised from the shallow shafts and pits by the use of horse-operated winches. These primitive operations were begun at the Soudan mine in the early eighties, and started the foundation of the world's largest and most productive iron-ore producing field. The original methods mentioned had been in use but a short while when it was discovered that the ore was high-grade and consequently in demand and valuable. The newly created demand for larger tonnages called for a change in mining methods, and while the newly constructed Duluth & Iron Range Railroad made it possible to bring mining equipment in to the mines, it also marked the advent of mechanical engineering in the mining industry. With the coming of the railroad, horse winches gave way to the first steam hoists. These were toy affairs compared to what was to follow, but they marked the first important improvement in the industry. Along with the steam hoist came the steam-operated piston drill for drilling blast holes in the rock and ore, displacing the slower and less efficient hand drills.

The introduction of the steam hoist called for head frames—small wooden affairs—and one-ton capacity ore buckets. As the production increased, the mines became larger, and wheelbarrows were displaced by 18-in. gage 1-ton-capacity ore cars that were pushed around by man power.

The demand for iron ore kept increasing to such an extent that the next step was the installation of larger hoisting plants, and the steam piston drills were discarded for those operated by compressed air. In all, the production per miner increased to the point where buckets were discarded for car cages that brought the 3-ton-capacity mine cars to the surface, where they were run off and dumped their loads on the stock piles.

The Steam Hoist of the Nineties

To handle these heavy loads at high speeds required a further increase in the size of the hoisting engines, so we see installed what was considered in the nineties the latest in steam hoists—a two-cylinder Corliss-valve steam-engine hoist. The engine had mounted on the crankshaft one pinion that meshed with two large gears mounted on two drum shafts. On the drum shaft were four clutch-operated rope drums approximately 10 ft. in diameter. Such machinery demanded higher steam pressure in larger quantities than could be supplied by the vertical boilers with their dutch-oven fireboxes in which local wood was the fuel, and so the later plants were designed and built for burning coal.

A serious handicap to any further increase in the production of iron ore was the delay occasioned by having to break up the large

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[1] Mechanical Superintendent, Shenango Furnace Co. Mem. A.S.M.E.

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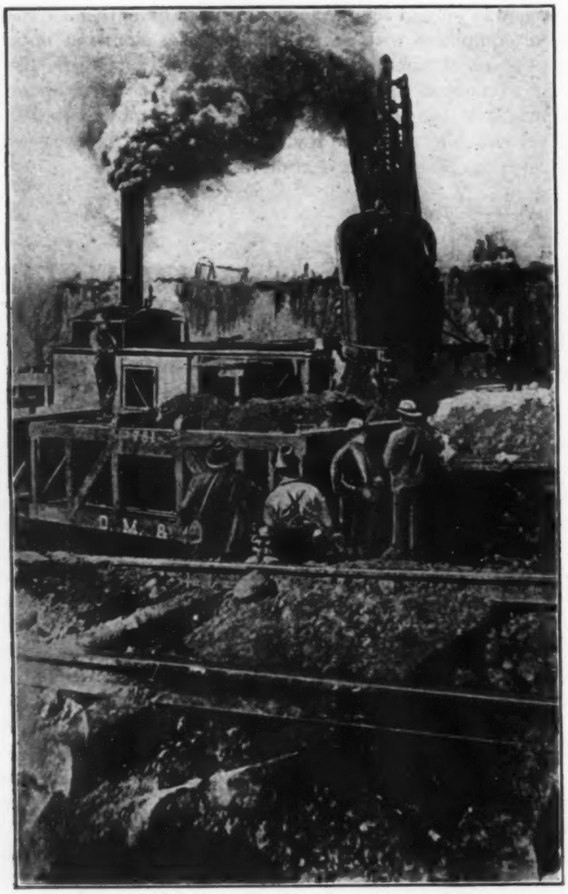
chunks of ore with hand sledges of the 20-lb. type, and to overcome this drag on production, there were next introduced the jaw crushers, usually in batteries of four, driven by a single-cylinder Corliss engine through a rope drive.

The adoption of all this mechanical equipment, however gradual, meant the introduction and development of another department in the business of mining iron ore—a department that was soon to be the dominant factor in this mammoth business. Planning, installing, and operating mechanical equipment of the then largest known types meant the presence of the mechanical



The First Steam Shovel on Mesaba Range

engineer; and the mining industry would be lacking in gratitude indeed, if at this point it failed to acknowledge its debt to our two ablest pioneers and mechanical engineers of outstanding ability, namely the late H. J. Wessinger, originally with the Minnesota Iron Company and later for many years chief engineer of the Oliver Iron Mining Company, and Richard Faull, who succeeded Wessinger with the Minnesota Iron Company and is at present mechanical engineer with the Tennessee Coal, Iron & Railroad Company. It was owing in a large measure to these able men that the early mechanical equipment was properly planned and introduced and the necessary personnel trained for its operation and maintenance, a personnel that subsequently carried on and is today largely responsible for the almost complete mechanization of our mining industry.

The introduction of mechanical equipment made necessary the building and equipping of repair shops for machinery maintenance purposes, but owing to the great distance of the mines from the factories, it was not long before manufacturing was carried on in considerable quantities. Complete rock drills of the No. 3 Rand type were made in the Soudan shop, and likewise ore cars, cages and skips, small steam engines, pumps, diamond-drill parts, and engines. In fact, the ability of Mr. Wessinger and Mr. Faull and the value of their influence on the industry can no better be described than when it is understood that these shops away up in what was then a wilderness not only made their own taps, dies, reamers, drills, gigs, templates, and gages but the necessary small tools used by the machinists, blacksmiths, and carpenters. It is also interesting to know that drop forging was quite a branch of the early mine shop of thirty years ago, although today it is of little importance to us and is seldom necessary because faster means of communication and transport have brought the factories closer to the mines.

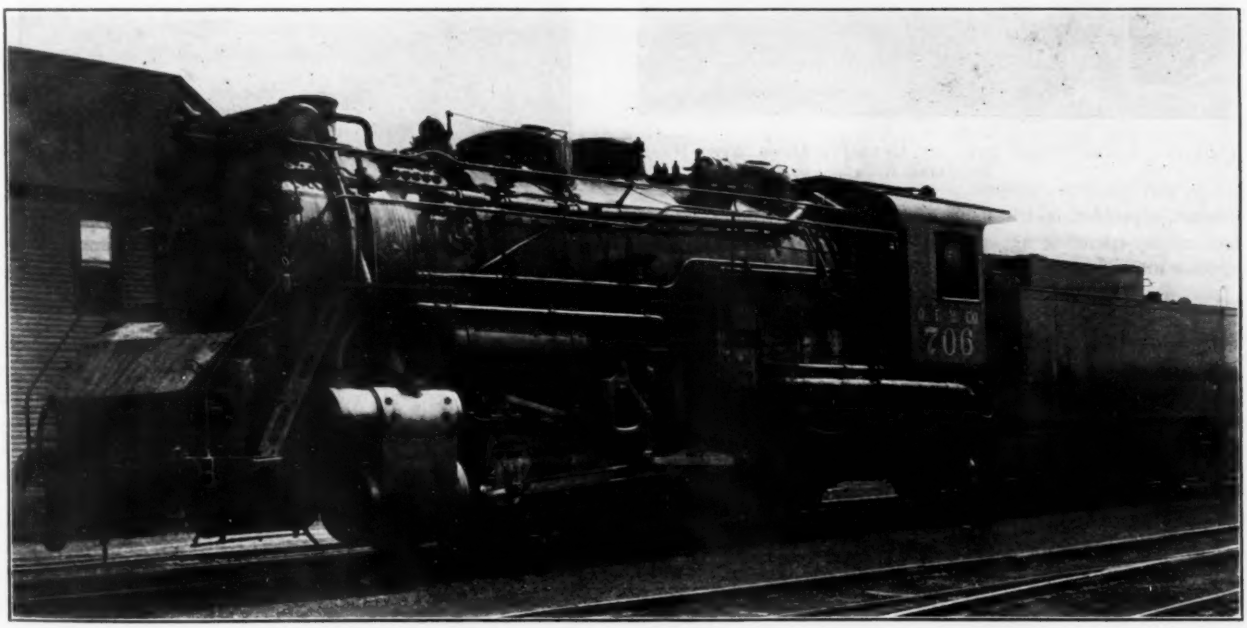
Advent of the Steam Shovel

The ever-present call for a larger output of ore at a less cost seemed temporarily solved so far as the direct production of the miners was concerned, and attention was therefore next directed to reducing costs in some of the non-producing branches; and the most notable of these was in loading the stock piles of ore that were accumulated during the winter months. It was the custom to load the stock piles with hand labor—hand shovels, wheelbarrows, small cars, anything available was used to load the accumulated ore into the 15- and 25-ton capacity railroad cars for transportation to the ore docks at Two Harbors. In loading these stock piles, it took so many men to do a reasonable amount of work that the base of the piles resembled busy ant-hills. This condition was subjected to a quicker and more telling change than any other phase of mining with the introduction of the steam shovel; and truly the early steam shovel was a grotesque affair when compared with the almost human electrical shovels we have today.

A word about the first steam shovel used in the Minnesota iron-mining industry. The make of the machine is unimportant and always provokes an argument among the old-timers, but the general description is as follows: It was a railroad-type machine with an upright steam boiler, one main single-cylinder engine that operated the hoist drum and propelled the machine through clutches. Swinging the boom was accomplished by wrapping a wire rope around the circle, one end going straight to a piston rod projecting from a steam cylinder that was about 8 ft. long, set on one side of the shovel, and the other end of the wire was passed around the shovel frame over pulleys and fastened to the other end of the cylinder. Moving the piston in either direction would have a resultant effect in swinging the boom. The dipper was forced in or out by means of a steam ram cylinder fastened to the other side of the boom by trunnions, the piston rod being fastened to the dipper handle just above the dipper. Steam was supplied to this ram cylinder through an ordinary steam hose. Judged by present standards, the first shovels were crude affairs mechanically, but wonderfully efficient when compared to the man power they displaced.

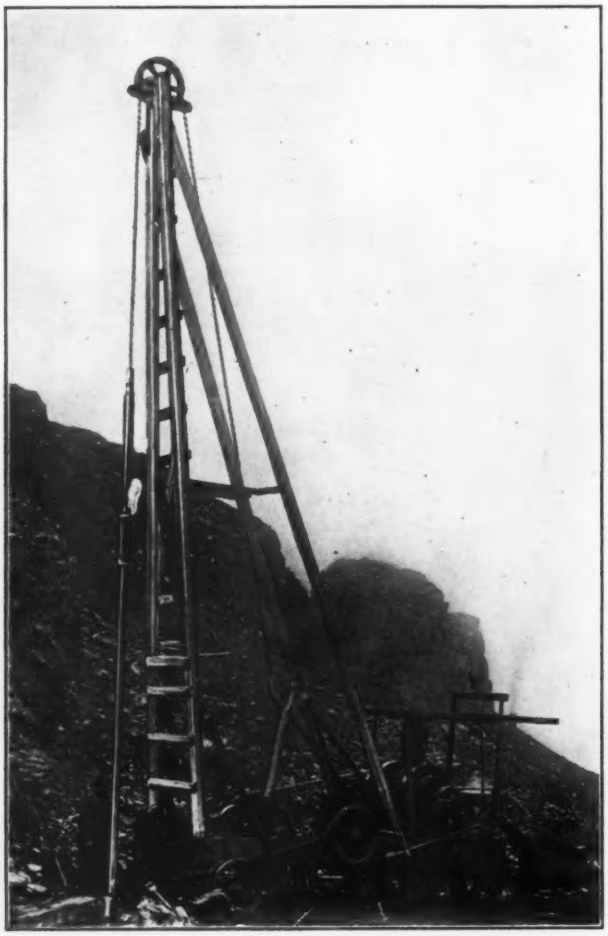
If space permitted and time allowed, it would be interesting indeed to recount and discourse on the many mechanical devices that were introduced and tried out by the pioneers in their attempts to facilitate production and reduce costs. For instance, there were water siphons up to 2000 ft. long; balanced tramming was used, where the loaded car going down grade raised a counterweight which pulled the empty car back; air lifts were used at all advantageous points; and of special interest to those at present interested in mining and improving its methods, particularly those interested in scraper hoists and underground loading machines, will be the fact that the first underground loading machine was designed by Mr. Wessinger and built in the Soudan shop just about 30 years ago.

Type of Shovel Used on the Range in the Early '90's



Locomotive Used in Open-Pit Service; Lima Locomotive, Class 080-S-254, 69,500 Lb. Tractive Power, Total Weight 448,000 Lb.

Coming down to the present day and the methods employed, we of course have had the benefit of the experience of others as well as the wonderful improvement in all lines of mechanical equipment. To the layman, our mining industry today is nothing if not spectacular, but to the engineer the problem grows more complex. The old problems of increasing production to supply a growing demand were solved long ago. Today we are confronted with the problem of lowering our producing costs to the point where it is possible to show a slight profit in a highly competitive



Drilling Blast Holes Into an Open-Pit Mine With Well-Drilling Rigs

market, a problem not in itself insurmountable if the tax-raising and money-spending agencies of the commonwealth would cooperate instead of taking a tangent to the common aim.

Mechanizing the Underground Operations

High production at low cost is the aim of both the open-pit mines and the underground mines. It should apply more particularly to the latter, because in the underground mines the production is naturally very limited, and to obtain low costs we are mechanizing more and more our underground operations. We are using hand-held air-operated jack-hammer drills for hard ground, and hand-held air-operated auger drills for the softer ground. Hand shoveling or mucking the ore into the cars is a thing of the past in most mines. All loading into the cars and chutes is now being done by the use of slushers, or scraper loaders, a machine consisting of an electric-motor-driven two-drum hoist with one pulling rope for hauling the loaded scraper and a tail rope for returning the scraper to the face. An indication of the usefulness and growing demand for these scraper loaders is that the earliest type, six years ago, had a $2\frac{1}{4}$-hp. motor, whereas today we have them as large as 20 to 50 hp., with either clutch or remote control. The net result is less arduous labor, greater production per miner, and a reduction in the cost per ton of ore produced.

The cars that are in use today in the underground range in size from the 1-ton-capacity sub-level type to the 5-ton main-level type, all equipped with ball or roller bearings. The main-level cars have half to three-quarter size automatic couplers to facilitate handling in trains and are run at high rates of speed over heavy steel rails. The cars used in the underground mines are all-steel, sturdily built, usually for 24-, 30-, or 36-in. gage track, with 14-

Surface Part of Open-Pit Drainage Pump; Pump Bowls Located 320 Ft. Below Motor Base

to 16-in.-diameter wheels. Chilled-iron wheels are considered preferable to manganese as being less abrasive on the rails, frogs, and switches. As yet, steel ties have been used but little in the underground mines, although there is only one objection to their use, and that is the initial cost. It is very probable that this objection would be minimized if an accurate check were made of the cost of hewing, cutting, and spiking the wood ties now most used.

The steam-engine, handbrake-operated hoists are being replaced with electric-motor-driven hoists, either directly connected or having a single gear reduction with herringbone gears and oil-operated post brakes. The latest hoists are equipped

for safety with overspeed and overwind devices. At the present time such electric hoists range in size from 100 to 1300 hp. (motor rating) and for depths of from 200 to 2000 ft.

The Pumping Equipment of Today

The underground drainage problem has been shifted from the old reliable, though sometimes bulky, steam pumps, requiring large pump stations underground and long steam lines, to the motor-driven centrifugal pumps or motor-driven multi-plunger pump.

A recent addition to our pumping equipment and one that gives great promise of further economies is the deep-well turbine-type pump. These pumps are installed in driven wells or in shafts with the pump bowls located near the bottom and submerged, the impellers being driven by an enclosed shaft connected to an electric motor located on the surface. The outstanding advantages lie in the facts that these pumps can be installed in driven wells, that they require very little attention, and that they cannot be drowned out through flooding as sometimes happens to a station pump. The deep-well turbine pumps in use in our mines today were installed principally for the purpose of draining the open-pit ore bodies, and are recognized as being the ideal equipment for this purpose.

The last few years have seen the continued abandonment of the isolated power plants with which every mine was equipped and the installation of electrically driven equipment. The result is a more flexible and efficient operation, with fewer men employed and a lower production cost.

When the underground mines operate during the winter, they accumulate stock piles of ore that are loaded during the shipping season into 50- or 75-ton-capacity steel ore cars by steam shovels as in previous times, except that the shovels are larger and more efficient; and where the shovels are electrically operated and have caterpillar traction, only two men are required to operate each one where formerly eight men were necessary.

The largest producers of iron ore on the iron ranges are the open-pit mines, and mines of this type have relegated the smaller underground producers to the point where their high cost and low production are at best a worry and sometimes a liability.

Mines of the open-pit type had their real start in the early nineties. The equipment used at that time included the ordinary contractor's scrapers, carts, and shovels, all of a type which can be seen today in any small grading or foundation job; but the growth of the industry was such as to create a demand for bigger and more efficient equipment, until today the machinery in our open pit is the latest, most efficient, and largest in existence for mining purposes.

Up to five or six years ago all of the shovels were of the steam type, ranging in size from the $1^1/_2$-cu. yd. dipper capacity, 50-ton type, to the 8-cu. yd. dipper capacity, 350-ton type. The average production shovel, however, was the standard railroad type having a 4-cu. yd. dipper, self-propelling on rail sections, 135-lb. steam pressure, approximately 85,000 lb. bail pull. These railroad-type shovels have lately been fitted with caterpillar traction to facilitate moving about the pit and to reduce the amount of labor servicing each machine.

Electric Power Shovel Introduced

About seven years ago the electric power shovels were introduced on the iron ranges, and while their general adoption was slow, it was not because of any lack of appreciation of their advantages, these being only too obvious, but rather it was because of a policy of watchful waiting until most of the objectionable features could be noted and corrected by the manufacturers. This policy of cooperation between the few users and the manufacturers was a wise one, because today we have not a large variety of makes of electric power shovels, but rather the shovels of only two manufacturers are in general use. It is impractical to describe in detail the various electric power shovels in this paper, but as an illustration, the most popular production shovel will be described briefly and will later be compared in operating cost with a steam shovel of like capacity. The details of the Marion or Bucyrus electric revolving shovels, 4-cu. yd. type, are as follows:

Length of boom	29 ft. 6 in.
Capacity of dipper	4 cu. yd.
Maximum dumping height	20 ft. 3 in.
Maximum dumping radius	37 ft. 0 in.
Width at level of floor	51 ft. 6 in.
Height of cut	39 ft. 0 in.
Capacity per hour	150–300 cu. yd.
Crawling traction truck (2)	36 in. wide by 16 ft. 3 in.
Total weight, approximate	360,000 lb.
Approximate bearing pressure crawler belt	25 lb. per sq. in.
Control	Ward Leonard (full voltage) direct current
Hoist generator	135 kw.
Synchronous driving motor on motor-generator set	250 kva.
Crowd generator	39 kw.
Swing generator	40 kw.
Hoist motor	230 volt d.c. 125 hp. continuous rated
Swing motor	230 volt d.c. 40 hp. continuous rated
Crowd motor	230 volt d.c. 40 hp. continuous rated
Bail pull on dipper	85,000 lb.
Dipper speed	128 ft. per min.
Propelling effort	115,000 lb.
Rotating effort	34,200 lb.
Propelling speed	0.70 m.p.h.
Crowding speed	120 ft. per min.
Crowding effort	68,000 lb.
Rotating speed	3 r.p.m.

Operating Comparison, Approximate

		Steam cost per shift		Electric cost per shift
Operator	1	$10.35	1	$10.35
Cranesman	1	7.55	0	....
Fireman	1	5.70	0	....
Oiler-helper	0	....	1	5.70
Pit men	5	21.70	0	....
Night watchman	1	5.70	0	....
Power for 1500 cu. yd. per shift		32.25		12.00
Interest on investment		7.00		11.60
Maintenance, season repairs, and Sunday watchman		9.00		3.00
		$99.25		$42.65

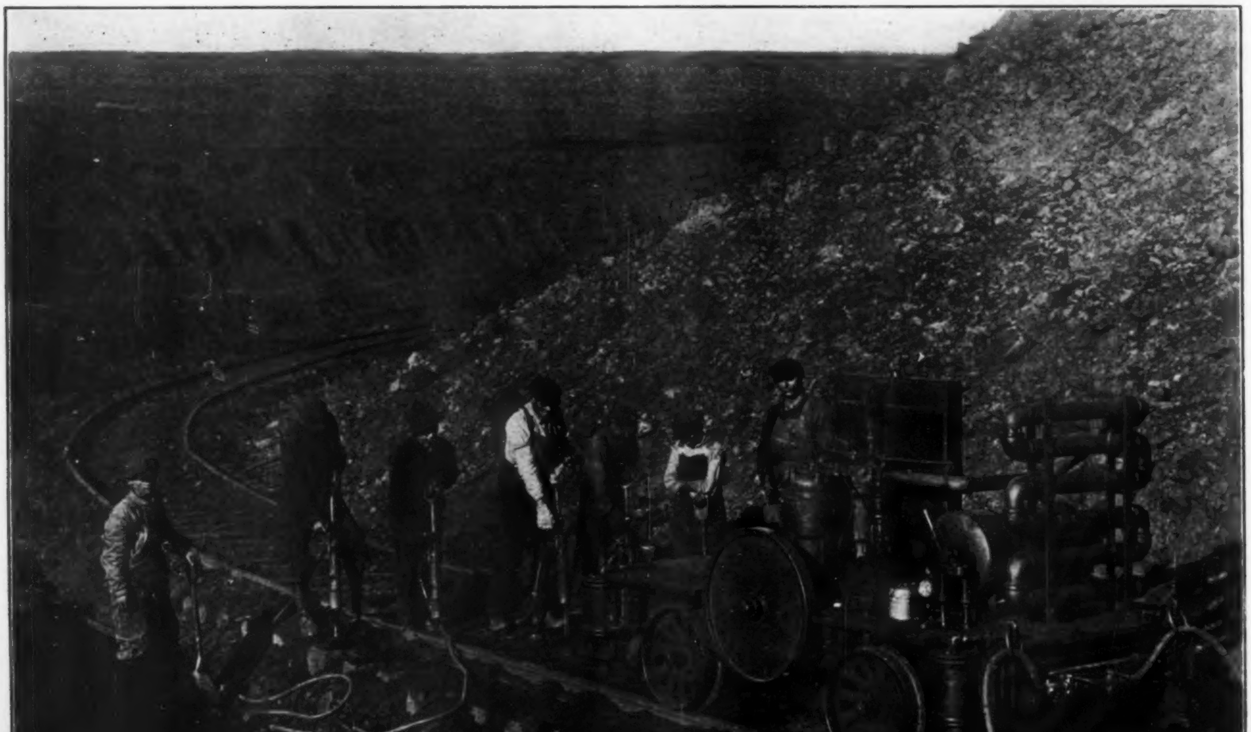
Features of the Latest Shovels

The figures shown certainly speak for themselves, require no comment, and are given merely to show the trend and the result of modern planning. It is of interest to note the fact that these later-type shovels have cut herringbone gears, enclosed ring-oiled bearings, pressure lubrication, bronze-lined bearings, castings of steel, alloy-steel shafts, motors and motor-generator sets have ball or roller bearings, and in all are as nearly automatic and fool-proof as it seems humanly possible to make them at the present time.

The figures just given refer of course to the standard loading shovel. There are a few smaller machines in use and many larger types as well. The latest additions to the latter class recently went into service in one of the open-pit mines, and the following few general details may be of interest on the Model 350 electric revolving shovel:

Power	Direct-current motors and motor-generator equipment, Ward Leonard (full voltage) control
Dipper handle, length	50 ft.
Boom, length	70 ft.
Dipper (wt. 30,000 lb.)	10 cu. yd.
Height of dump above grade	55 ft. 6 in.

Largest and Latest Type Electric Revolving Shovel, Loading Stripping; Dipper Capacity of 10 Cu. Yards



Portable Air Compressor and Tie Tampers at Work on One of the Open-Pit Tracks

THE LATEST MARION PRODUCTION SHOVEL, ELECTRICALLY OPERATED, TRACTOR TYPE WITH 4-CU. YARD DIPPER

Weight	1,250,000 lb.
Crawling traction trucks	2
Hydraulic equalizing of shovel frame.	
Bail pull	140,000 lb.

This shovel can be seen in operation at Calumet, Minn., in stripping work, and represents the largest and latest in electrically operated shovels in use anywhere.

The motive power in the pits is next in importance to the shovels. The locomotives range in size from the 60-ton 0-6-0 class, 180-lb. steam pressure, 19- by 26-in. cylinder, 28,500 lb. tractive effort, simple switchers, to the latest heavy Lima switch engines of the 0-8-0 type weighing 452,000 lb. each, with tender-type boosters, 225-lb. steam pressure, superheated steam, underfeed stoker with power grate shakers, Baker valve gear with power reverse, feedwater heaters, and other late features that make up the latest type of steam locomotives. There are several electric locomotives on trial at different mines that are controlled through automatic stations, and while their operation gives great promise of further economies, their general adoption is deferred pending further observation and improvements.

TYPES OF ORE-HAULING CARS

There are two classes of cars used in the pits. One is the standard 50-ton and 70-ton all-steel ore cars that are the property of the railroads and are hauled in trains to the ore docks after being loaded in the pits, and the other class is the mine-owned all-steel dump cars ranging in size from 16 to 30 cu. yd. capacity, equipped with air brakes and large air cylinders on each side of the center frame for dumping the loads.

The railroad equipment in the pits necessitates the use of locomotive cranes for wrecking and loading purposes. These cranes are all steam-operated, of standard types ranging in size from 10-ton lifting capacity to the larger 50- and 70-ton sizes. Other equipment used in the pits includes track-shifting machines, air compressors operating tie tampers and hammer drills, and electrically operated well-type blast-hole drilling rigs.

In connection with certain pits having ores that require beneficiation, there are ore-washing plants for removing the free silica from the ore through agitation in water. The washing plants have been developed over a period of years and range in capacity from 125 tons per hour to several thousand tons per hour.

A later class of beneficiation plant to be added to the open-pit equipment is the crushing and screening plant for screening out the large lumps of ore and crushing them to shipping sizes. These crushing and screening plants are mammoth affairs, and to describe them adequately would require a separate paper. It is probably sufficient to the purpose of this paper to say that whole trainloads of ore from the pits are dumped into the bins at one time, and the material is screened, crushed, and reloaded into ore cars within the space of a very few minutes.

With the almost complete mechanization of the iron mines, with mechanical equipment of almost every size and description, it is only natural that the repair and maintenance departments should be supplied with well-built and well-equipped repair shops. Here again we see a variety of sizes, and these shops are best described as being somewhat on the order of the average railroad shops. Very little if any manufacturing is done, because the multiplicity of parts used and their intricate designs would call for a huge investment in shop equipment; so consequently the mine shops confine themselves to repair work similar to that handled by the average small railroad shops. The shop equipment is up to date in every respect; special steels are used and properly handled; also autogenous and electric welding are as common as in other modern shops.

Modernization Without Accident Increase

An interesting sidelight on the increasing use of machinery in the production of iron ore is in the fact that there has been no increase in the accident hazard. This result is being achieved because the safety of the employee is always the first consideration when laying out or purchasing new equipment. The problem of the employee's safety has become so important at the mines that each mining company has a separate department whose sole duty is to cooperate with employees, foremen, and superintendents for the greater safety of every one on the payroll.

This paper at best can only give one a sketchy view of what mechanical engineering has accomplished in the iron-ore industry. It is impractical to give in this paper detailed descriptions of our interesting plants and machines; these can easily be obtained on inquiring. Among other things, it has been necessary to omit reference to many difficult engineering problems that crop up and confront the engineer engaged in the mining business. Except in a very few instances he is responsible for the design, installation, and general operation of all equipment covering the steam, hydraulic, electrical, compressed-air, transportation, structural, and maintenance fields, and his job is interesting indeed because of the opportunity to practice engineering in its fullest sense and meaning.

Progress in Lubrication Research

AT THE Annual Meeting of the Society in December, 1927, the A.S.M.E. Special Committee on Lubrication, Mayo D. Hersey,[1] Chairman, presented a "Progress Report in Lubrication Research," at a Lubrication Research Symposium. This report has been published in the *Transactions* of the Society, Applied Mechanics Section, January–April, 1928, as paper No. APM-50-4. The report refers to a paper by Mayo D. Hersey and Henry Shore[2] entitled "Viscosity of Lubricants Under Pressure," which reported an experimental determination of the combined effects of high pressures and temperatures using the ball-and-slanted-tube type of viscometer, published in Mechanical Engineering, March, 1928, pp. 221 to 232. An appendix to the report contains the results of some experiments by Robert V. Kleinschmidt[3] on the viscosity of lubricating oils under high hydrostatic pressure which were conducted in the laboratory of Prof. P. W. Bridgman at Harvard University, and which confirm the apparent solidification of lard oil under high pressure observed by Hersey and Shore. The following discussion took place after the presentation of the progress report.

John M. Lessels.[4] The report deals with basic fundamental data more or less related to the quality of the lubricants themselves. It is to be hoped that the report will be continued, because it will undoubtedly throw a great deal of light on several things we know nothing about, such as oiliness. Another point in the report is the inclusion of the bibliography. It is to be hoped that this practice will be continued, because it keeps us posted on the work being done, not only in this country, but in others.

The requirements of industry are rendering investigations necessary on large-size bearings. It is precisely this state of affairs which has compelled the Westinghouse Co. to begin work on the study of large-size bearings, and some of the results of Mr. Karelitz's work on this subject have been published already. It is to be hoped that in the future we shall have further contributions to make. It might be well to bring out here the danger of drawing inferences from tests on small-size bearings. As to what the proper size should be, that must be left, probably, to the committee.

As we see it, the report has been stressing more or less the physical side rather than the engineering side. My only plea is that the funds will be increased so the committee will be able to extend its scope and be able to foster actual bearing tests in large-size bearings so that we shall have data not only on the physical aspects, which of course are very desirable, but also on the engineering aspects of the problem.

Henry Shore. I have been interested in Dr. Kleinschmidt's experiments and, having worked along similar lines, I can appreciate the effort required to get pressures above 4000 atmospheres. There is one very interesting thing in this paper which apparently was not noticed; the effect of temperature on the solidification pressure, or the pressure at which solidification took place. Dr. Kleinschmidt's data being more complete than our own as regards solidifying points, I plotted on a piece of ordinary graph paper the solidifying pressure against temperature. (See Table 1.) Of course, there are only three points for each oil, but a rather startling thing happened when, regardless of the oil used, the slope of that line apparently was a constant. There is lard oil represented, Three-In-One, Veedol, sperm oil unrefined, and a sample of sperm oil from the National Physical Laboratory in England. All these, with the exception of the sample from Eng-

TABLE 1 SOLIDIFYING PRESSURES AT VARIOUS TEMPERATURES

Oil	Temperature, deg. cent.	Solidifying pressure, kg. per sq. cm.
Lard	25	2700
	40	4200
	75	7200
3-in-1	25	2200
	40	..
	75	6500
Veedol, med.	25	1700
	40	3000
	75	..
Sperm (unrefined)	25	1200
	40	2100
	75	5100
Sperm (N.P.L.)	25	800
	40	1800
	75	4300

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[4] Engineer in charge of Mechanics Section, Research Department, Westinghouse Electric and Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

land, have the same slope which corresponds to about 85 kg. per sq. cm. for each degree centigrade. I think Dr. Kleinschmidt's work should be continued and a more complete range taken to justify this correlation.

G. B. KARELITZ.[5] At present an investigation of the operation of oil-ring-lubricated bearings is in progress at the Westinghouse Elec. & Mfg. Co., in East Pittsburgh, Pa. This type, the most common in electrical apparatus of a medium size or of a comparatively low speed, has not been given sufficient consideration. Most of the work being done in the United States on lubrication is connected with automobile bearings, which is natural when the number of such bearings in use is taken into consideration. This is also explained by the fact that little trouble has been experienced in the past with large bearings, but it is conceivable that difficulties will arise in the near future when the pressures and speeds in bearings will advance even further than in present-day design.

There is no doubt that other companies do much work on bearings and lubrication. It may be well for the Research Committee on Lubrication to coordinate this work and probably to attempt a distribution of different phases of the problem among various concerns. This would eliminate wasteful duplication of work and be to mutual benefit. Such a coordination should not meet much opposition since, to the writer's mind, exchange of data on lubrication would not involve a disclosure of any important technical secrets.

JOHN E. YORKSTON.[6] For a good many years the General Electric Company has been working along the same lines as those just mentioned and has reached a stage where it has experimented with bearings in order to determine the curves for the designers. These curves have been very satisfactory as far as progress in the design of the bearing was concerned; but as they were determined some years ago, they are of very little value today because of the increase of pressures and speeds and also because of changes both in bearings and in material from which the bearings are made.

I would like to raise the question regarding the pressure and speed at which the lubricant will vaporize; because, today, in high-speed machinery the greatest trouble and cause for complaint is due to vaporization and leakage from bearings; especially in electrical apparatus, because of the tendency to injure the apparatus and the insulation.

LESTER CAMPBELL.[7] I can cite an experience I have had with bearings and lubrication in the application of a bronze bearing to a steel spindle on a test which was run in our plant for about a week. The proper allowance for running had been provided for according to the usual custom. In five days it was reported that the bearing was an absolute failure. It was found that the department which made the bronze bearings blamed the department which made the spindle, while the department that made the spindle knew the trouble was with the bronze bearings. Upon seeing the actual running conditions, I found the cause of the trouble to be this: The bronze bearing was absolutely correct and the spindle was absolutely correct. The action of cotton waste packing in filtering lubricating oil has been referred to already. The waste that had been used had been put in by mistake, cotton waste having been used, and it filtered the oil beautifully. In fact, it stopped the lubrication entirely. As soon as wool waste was substituted for the cotton waste the bearing became a success.

ALVAN L. DAVIS.[8] Although rather far afield from the high speeds in turbines, it may be interesting to know that in certain rolling-mill work in the cold-rolling of metals, where very high bearing pressures are used, and where grease rather than oil is used as a lubricant, we appear to get very low coefficients of friction when things are running well: certainly down to 0.005 and probably as low as 0.0025. Probably you wonder how we determine any such figure, and I must admit that it is derived indirectly. Knowing the amount of power put in, and being able to compute quite accurately what goes in the other directions, what goes into the roll necks is determined by taking the difference, and therefore, as the pressure is known, we get the coefficient of friction. Of course, in working with such a low coefficient things will go wrong very rapidly, once they start, due to impaired lubrication.

EVERETT O. WATERS.[9] It may be of interest to determine what, if any, effect the increase of viscosity with pressure has in ordinary bearing applications where the unit pressures are of the order of a few hundred pounds per square inch or less. I made such a comparison taking as a basis a cylindrical bearing in which the shaft is approximately 4 in. in diameter, speed about 1000 r.p.m., the allowance measured on the diameter about 1/100 in., and viscosity corresponding to about 100 Saybolt. On the basis of viscosity being constant, it is possible, using Harrison's equations, to determine the unit pressure on the journal, the total pressure on the journal, the moment of the force of friction, etc. It is also possible, starting out with the fundamental hydrodynamic equations, to derive a relation between the unit pressure on the journal and the position of the point on the journal at which that pressure is measured, taking account of the variations in viscosity with pressure. The difference in results between what one obtains with constant viscosity and varying with pressure is very small as might naturally be expected. The result obtained indicated that the increase in load would be in the order of 1 to 2 per cent when the eccentricity factor c was 0.2. Taking that same bearing, increasing the load so the eccentricity factor is about 0.7, which gives a load of about 250 lb. per sq. in., and going through the calculations again, we find that by taking account of the increase in viscosity the load is about 6 per cent greater.

These figures are presented to show how this pressure-viscosity relation has only a small application in the field of ordinary journal bearing lubrication. That, however, does not take account of possible high spots on the surface of the bearing or journal, and the irregularities one always finds in a new bearing.

Of course, there will be places where the pressure is extremely high over very small areas; and from the results which Messrs. Hersey and Shore obtained, it would appear that in all such cases the lubricant has what might be considered an inherent safety factor, which would allow the bearing to take a heavier load than would be the case if viscosity were constant.

JEAN J. TRILLAT,[10] in a written communication, expressed his hope of visiting the United States on some future occasion for the purpose of discussing lubrication research, and contributed a copy of his paper, *Les Théories Modernes sur la Lubrification.*[11]

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[10] Ingénieur; Docteur ès Sciences; 6 Rue Daubigny, Paris, France.

[11] An extended abstract will be found in MECHANICAL ENGINEERING, vol. 50, no. 6, June, 1928, pp. 471–473.

Aluminum Alloys

Pure Aluminum—Aluminum Casting Alloys—Aluminum-Silicon Alloys—Improvement of Mechanical Properties by Heat Treatment—Die-Cast and Permanent-Mold Alloys—Strong Aluminum Alloys and Their Applications

By ZAY JEFFRIES,[1] CLEVELAND, OHIO

THE real aluminum industry dates from the late eighties when Charles M. Hall, a student at Oberlin College, conceived the idea of producing aluminum by dissolving chemically purified bauxite, a hydrated oxide of aluminum, in cryolite and reducing it electrolytically at a temperature near 1000 deg. cent.

When the aluminum is reduced it is cast into pigs, and as these pigs contain some bath impurity they are remelted and refined in an open-hearth or similar type of furnace and the molten metal then cast into ingots. These aluminum ingots generally contain at least 98 per cent aluminum and a very considerable proportion contain more than 99 per cent.

Aluminum of 99.98 Per Cent Purity

In recent years metal of 99.98 per cent purity has been made by a special process devised by the late William Hoopes of the Aluminum Company of America, ably assisted by Dr. Frary, Director of Research for the Aluminum Company of America, and Mr. Edwards, Assistant Director of Research.

The obtaining of this very pure metal was a great metallurgical achievement. The process comprises a three-layer bath: a bottom layer consisting of an alloy of aluminum and a heavier metal, for example copper, a molten non-metallic bath of greater density than molten pure aluminum, and an upper layer composed of the pure liquid aluminum. The aluminum is transferred electrolytically from the lower high-specific-gravity alloy through the bath to the floating layer of pure aluminum, and is tapped from the upper layer.

Aluminum Casting Alloys

Pure aluminum is used only to a limited extent in the castings industry, as its properties are not such as to lend themselves to structural uses. The tensile strength is around 12,000 or 13,000 lb. per sq. in. and the elongation on the order of 25 per cent. However, these properties can be changed considerably by varying methods of casting and by varying the purity of the aluminum.

Of the binary alloys there are only three types which are used to any considerable extent. These are the aluminum-copper, the aluminum-manganese, and the aluminum-silicon alloys. Most of the alloys of commerce are ternary alloys or even contain four or more elements, but their bases are as a rule aluminum-copper or aluminum-silicon. One alloy, aluminum-manganese, is quite an important binary alloy. When about $1^1/_4$ per cent of manganese is added to commercially pure aluminum, the tensile strength is substantially increased and the other properties are sufficiently near the properties of commercially pure aluminum that the alloy can be substituted for the latter in most places. Furthermore the $1^1/_4$ per cent of manganese does not detract from the splendid corrosion-resisting properties of the nearly pure aluminum. This alloy is very important in the wrought-metal field, and is used to a slight extent in the castings industry also.

Table 1 gives a list of what might be termed the standard alloys of aluminum for sand-casting purposes. Two of these, Nos. 12 and 112, or S.A.E. Nos. 30 and 33, are more used than any other alloys in the sand-casting aluminum art.

Another aluminum-copper alloy containing about 12 per cent of copper is used for certain purposes, especially where leakproof characteristics are desired and where more hardness is desired than obtains in the other two alloys. This alloy is somewhat more brittle than the 8 per cent copper alloys, and for that reason is not as good a structural casting alloy as the S.A.E. 30 or 33.

Aluminum-Silicon Alloys

The aluminum-silicon alloys have been used now for only about six years. Dr. Pacz made the discovery that whereas aluminum-silicon alloys containing, say, 87 per cent of aluminum and 13 per cent of silicon were relatively coarse-grained when cast normally in sand and relatively weak and brittle, they were fine-grained, strong, and tough when treated in the liquid state before casting with a small quantity of sodium fluoride.

Fig. 1 shows the structure of an aluminum-silicon alloy containing approximately 13 per cent of silicon as cast in sand. When that alloy is treated with about 2 per cent by weight of sodium fluoride flux in the liquid state and then poured in sand, the type of structure changes to that shown in Fig. 2. This is called a "modified" structure. The eutectic is so fine that the silicon is really not resolved at the magnification shown—many of the particles are not at least—and the white material is nearly pure aluminum which contains some silicon in solid solution. The alloy normally should have contained excess silicon, so that the addition of sodium fluoride has modified the whole system.

The explanation for this has been fairly well worked out. Dr. Frary, Mr. Edwards, and Mr. Churchill discovered that this same general effect could be produced by adding metallic sodium. It is now considered that what Dr. Pacz did in his operation was to reduce metallic sodium from sodium fluoride, using aluminum as the reducing agent. The sodium is supposed to dissolve to a slight extent in the liquid aluminum and on cooling separate out into very fine particles and interfere with the free crystallization of the silicon. It so interferes with the crystallization of the silicon that the eutectic freezing point is lowered, and thus an alloy near the eutectic composition is changed to one in which the final structure is excess aluminum plus eutectic instead of excess silicon plus eutectic. This eutectic then will be richer in silicon than the so-called normal eutectic.

The 13 per cent silicon alloy in the modified condition has a tensile strength of 25,000–30,000 lb. per sq. in., an elongation of 5–10 per cent, and other properties as seen in Table 1.

The great value of these aluminum-silicon alloys in the castings art is not, however, in their physical properties. That is, it is not essential that the aluminum-silicon alloys have very high physical properties in order to justify their use. They are very fluid in the liquid state, and at the freezing point they are very tough. Because of both of these characteristics the aluminum-silicon alloys are used very extensively in pressure die castings. The walls of such castings are very thin and hence it is desirable

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Sections of an address on the general subject of aluminum delivered at a meeting of the Cleveland Section of the A.S.M.E., Cleveland, Ohio, March 1, 1927.

TABLE 1 ALUMINUM CASTING ALLOYS

(Properties obtained from unmachined sand-cast test specimens)

Alloy No.	Approximate composition, per cent	Ultimate tensile strength, lb. per sq. in.	Elongation, % in 2 in.	Approx. yield point, lb. per sq. in.	Brinell hardness number
100	Aluminum 99	12,000–14,000	15–25	4,000	25
12	Copper 8 (S.A.E. No. 30)	18,000–23,000	1–3	10,000	65
112	Copper 7.5 Zinc 1.5 Iron 1.2 (S.A.E. No. 33)	19,000–24,000	1–2.5	11,000	65
109	Copper 12	19,000–26,000	0–1.5	15,000	70
43	Silicon 5 (S.A.E. No. 35)	17,000–21,000	3–7	7,000	40
45	Silicon 10	19,000–23,000	1–3	9,000	50
47	Silicon 13 (modified)	25,000–30,000	5–10	11,000	60
106	Manganese 2	16,000–20,000	3.5–6.5	6,000	40
195	Copper 4 (heat treated)	28,000–35,000	5.5–11	18,000	70
196	Copper 5 (heat treated)	36,000–45,000	0–2.5	27,000	115
145	Zinc 10 Copper 2.5 Iron 1.2	25,500–34,000	3–6	12,000	65

to have great fluidity in the molten metal, and as the tendency to crack in a die casting during freezing and shortly after freezing

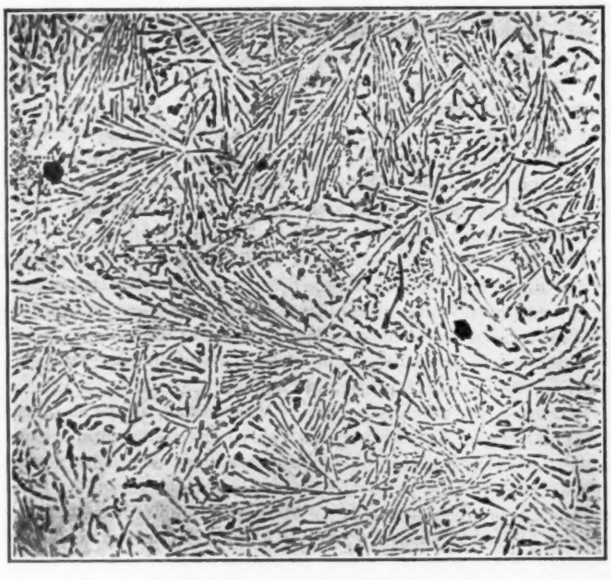

Fig. 1 Normal Sand-Cast Aluminum-Silicon Alloy Containing 13 Per Cent of Silicon. ×100

is considerable, the use of aluminum-silicon alloys minimizes two of the greatest difficulties in the die-casting art.

The severe chilling of the aluminum-silicon alloys in a pressure die or in a permanent mold also refines the structure, somewhat like the addition of sodium, and this refinement produces better physical properties than are obtainable in the sand-cast unmodified alloys. In this country the so-called normal alloys containing 5 per cent and about 10 per cent silicon are used in sand castings in addition to the 13 per cent silicon alloy in the modified condition. There is also extensive use in chill molds of unmodified alloys containing up to 13 per cent or even as high as 16 per cent silicon.

Heat Treating Aluminum Alloys

The alloys Nos. 195 and 196 represent an innovation in the castings industry. The theory of this will be considered a little later, but at the moment attention is called to the fact that the composition is aluminum plus substantially 4 to 5 per cent of copper. By proper heat treating, which involves holding at a

TABLE 2 PROPERTIES OF HEAT-TREATED ALUMINUM CASTINGS

Alloy No.	Grade	Tensile strength, lb. per sq. in., Min.	Avg.	Max.	Elongation, % in 2 in., Min.	Avg.	Max.	Brinell hardness (1000 kg., 10 mm.), Min.	Avg.	Max.
195	1	28,000	31,000	38,000	6.0	8.0	12.0	50	65	80
195	2	30,000	33,500	40,000	3.0	4.5	8.0	70	75	100
195	3	36,000	41,000	50,000	0.0	1.5	5.5	80	100	140
196	.	32,000	40,000	48,000	0.0	2.0	5.0	..	100	...

temperature a little below the fusing point of the eutectic or the most fusible constituent present for a considerable period of time, followed by rapid cooling, with or without a further heat treatment called artificial aging, the properties as shown in Table 1 are obtainable.

With the 196 alloy, which is artificially aged after the rapid cooling treatment, the tensile strength and yield point are increased at the expense of elongation.

The properties can be varied considerably from the figures given by varying the heat treatment and the method of casting, and by using certain other variations.

The aluminum-zinc alloys are not much used in this country and have not been for the last ten or twelve years. Alloy No. 145

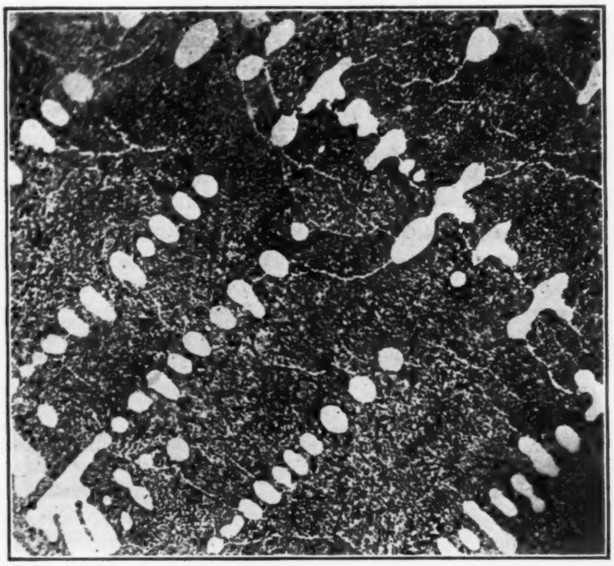

Fig. 2 Modified Sand-Cast Aluminum-Silicon Alloy Containing 13 Per Cent of Silicon. ×100

finds a limited use in places where considerable strength and toughness are desired.

Table 2 shows a little more in detail some of the properties which have been obtained from the 195 alloy. By using a very pure aluminum base and by careful alloying and heat treatment, Messrs. R. S. Archer and L. W. Kempf have been able to obtain tensile strengths in aluminum sand-cast bars of 40,000–44,000 lb. per sq. in. with about 18 per cent elongation, properties never even hoped for a few years ago in sand castings which were made of aluminum.

Permanent-Mold Aluminum-Alloy Castings

Table 3 gives the properties of a few of the pressure die-casting alloys, while Table 4 presents similar data on permanent-mold aluminum alloys, that is, aluminum alloys cast in iron molds without the use of pressure. A considerable variety of properties is obtainable using somewhat similar alloys to those previously described for sand casting. The permanent-mold process introduces a chilling effect which is very helpful with respect to the physical properties.

TABLE 3 MECHANICAL PROPERTIES OF DIE-CAST ALLOYS

(Obtained from round die-cast test specimen, 0.252 in. in diameter)

Alloy No.	Approximate composition, per cent	Tensile strength, lb. per sq. in.	Elongation, % in 2 in.	Brinell hardness number
83	Copper 2 Silicon 3	25,000–28,000	3–6	55–65
85	Copper 4 Silicon 5	28,000–30,000	2.5–4	60–70
13	Silicon 13	28,000–30,000	1–3	70–80

TABLE 4 PHYSICAL PROPERTIES OF PERMANENT-MOLD CAST ALLOYS

(Standard 0.505-in. test specimen, cast in permanent mold)

Alloy No.	Approximate composition, per cent	Tensile strength, lb. per sq. in., Min.	Max.	Elongation, % in 2 in., Min.	Max.	Brinell hardness number
43	Silicon 5.0	18,500	24,500	3.0	8.0	40–45
108	Copper 4.5 Silicon 5.5	21,000	29,500	1.0	4.5	65–80
45	Silicon 10.0	24,500	29,500	4.5	10.0	45–56
112	Same as sand-cast 112 (as cast)	21,000	29,000	1.5	3.0	70–90
122	Copper 10.0 Iron 1.2 Magnesium 0.25	22,000	30,000	0	1.5	85–105
125	Silicon 5.0 Iron 1.0 Tin 2.0	17,500	22,500	4.3	8.0	40–45
151	Copper 5.5 Iron 1.0 Tin 1.0	20,500	26,500	3.5	7.5	60–70
152	Copper 10.0	20,500	29,500	1.0	3.0	85–110
195	Copper 5.5	22,000	28,000	3.0	6.0	60–70
	Heat-Treated Alloys					
	Heat treatment No.					
195	4	35,000	39,000	5.0	9.0	70–90
195	10	48,000	54,500	1.0	1.5	110–140
122	2	24,000	30,000	0.5	1.5	90–120
122	7	40,000	48,000	0.5	1.0	125–160
122	12	24,500	32,500	0.5	1.0	125–160
122	14	24,000	30,500	0.5	2.0	95–125
122	15	26,000	32,500	0.5	1.5	115–125

TABLE 5 MECHANICAL PROPERTIES OF STRONG ALUMINUM ALLOYS

17S Alloy		17SO	17ST
Tensile strength, lb. per sq. in.		25,000–35,000	55,000–63,000
Yield point, lb. per sq. in.		7,000–10,000	30,000–50,000
Elongation, per cent in 2 in.		12–23	18–25
Brinell hardness (500 kg., 10-mm. ball)		42–50	90–110
25S Alloy	**25SO**	**25SW**	**25ST**
Tensile strength, lb. per sq. in.	25,000–35,000	45,000–53,000	55,000–63,000
Yield point, lb. per sq. in.	7,000–10,000	18,000–25,000	30,000–40,000
Elongation, per cent in 2 in.	12–23	15–20	18–25
Brinell hardness (500 kg., 10-mm. ball)	45–50	70–85	90–110
51S Alloy	**51SO**	**51SW**	**51ST**
Tensile strength, lb. per sq. in.	14,000–18,000	30,000–40,000	45,000–50,000
Yield point, lb. per sq. in.	40,000–60,000	15,000–20,000	30,000–40,000
Elongation, per cent in 2 in.	15–30	20–30	10–18
Brinell hardness (500 kg., 10-mm. ball)	25–32	55–70	85–100

Strong Wrought Aluminum Alloys

Although the aluminum-manganese alloy is a wrought alloy, it is generally considered to be more in the commercially pure aluminum class than the class of alloys shown in Table 5. This group of alloys is popularly known as the "strong-alloy" group. There are three alloys listed here called 17S, 25S, and 51S. The composition of the 17S alloy is approximately 4 per cent copper, $^1/_2$ per cent magnesium, and $^1/_2$ per cent manganese.

"17SO" indicates that the 17S alloy is in the annealed condition. The properties obtained in the second column under the caption "17ST" show what can be accomplished by heat treating this alloy. The heat treatment consists in raising the temperature to about 500 deg. cent., rapidly cooling, and then allowing the material to stand at room temperature for from one to four days. Immediately after cooling the tensile strength is on the order of 45,000 lb. per sq. in., but it begins to increase on standing, and at the end of about four days it has reached a value between 55,000 and 63,000 lb. per sq. in., which represents substantially the maximum strength obtainable by heat treatment of this alloy. The yield point and the Brinell hardness number are increased very substantially by heat treatment, while the elongation is but little affected.

The 25S alloy has different heat-treating characteristics and consequently its properties are listed in three distinct columns. The 25SO or 25S annealed alloy has about the same characteristics as 17SO, and 25ST has the same characteristics as 17ST. The 25SW column represents the properties after quenching and standing at room temperature. This alloy does not age substantially at room temperature. The composition is different from 17S in that it contains no magnesium. It contains somewhat more manganese and a higher silicon content and somewhat higher copper content than 17S. 25S after quenching has its properties changed to the values shown under 25SW. These values will remain substantially as shown for at least a year, and there is every reason to believe very much longer.

By reheating to about 150 deg. cent. a further increase in strength, yield point, and hardness is obtained. The properties of this artificially aged material are given in the column 25ST.

The 51S alloy contains substantially 1 per cent of silicon and an amount of magnesium which can vary within considerable limits, say, 0.5 to 1 per cent. In the annealed condition the alloy is very soft—not much unlike commercially pure aluminum. By quenching at a high temperature and aging at room temperature, the tensile strength is raised to nearly 40,000 lb. per sq. in. This alloy ages substantially at room temperature after quenching, but apparently will never reach its maximum properties by room-temperature aging. To obtain maximum strength, yield point, and hardness the aging temperature must be increased to, say, 150 deg. cent., and then the properties shown under 51ST in Table 5 can be obtained.

This 51S alloy is very soft at a high temperature, and shapes can be made of it which are very difficult in the other two alloys. It has nearly the pure-aluminum working properties, with physical properties nearly comparable with those of duralumin.

These strong alloys are made in all sorts of shapes—in sheet, wire, machining rod, forgings, and tubing.

In considering the application of these strong alloys as structural materials, Mr. Archer has drawn up some comparisons which are fairly simple but which give a very complete picture of the comparative properties of steel and the structural aluminum. These are shown in Table 6. For a definite basis of comparison he has considered a steel of 100,000 lb. per sq. in. tensile strength and a 50,000-lb. per sq. in. strong aluminum alloy. The moduli of elasticity are 30,000,000 for steel and approximately 10,000,000 for any aluminum alloy. The specific gravities are about 7.9 for steel and 2.8 for aluminum alloy.

TABLE 6 PROPERTIES OF STEEL AND ALUMINUM BEAMS OF GEOMETRICALLY SIMILAR CROSS-SECTION

	a	a^2	a^3	a^4	Weight	Strength	Stiffness
Steel	1	1	1	1	100	100	100
Aluminum	1	1	1	1	35.4	50	33.3
Aluminum	1.32	1.732	2.28	3	61.4	114	100
Aluminum	1.68	2.82	4.74	7.98	100	237	265

Assumptions

	Specific gravity	Young's modulus, lb. per sq. in.	Tensile strength, lb. per sq. in.
Steel	7.9	30,000,000	100,000
Aluminum	2.8	10,000,000	50,000

At the present time these strong aluminum alloys are used in the manufacture of screw-machine products and for forgings. Most of the propellers on aircraft in this country at the present time are made of the strong aluminum alloys, and they are also being used in the manufacture of chairs which weigh only about one-third what ordinary wooden chairs do. They are also being used to a considerable extent in the construction of railroad passenger cars, and a street car has been constructed in Cleveland largely from these strong alloys.

A Suggestion for Rating Steam Boilers

By W. A. SHOUDY,[1] NEW YORK, N. Y. and W. H. JACOBI,[2] KEOKUK, IA.

Each pound of the gases resulting from the combustion of commercial fuels with 20 per cent of excess air has a heat content of approximately 1000 B.t.u. (= 1 kilotherm). Since furnace conditions vary so widely, a "furnace factor" must be used which represents the ratio of the actual heat content of the pound of gases to 1000 B.t.u. The authors suggest as a substitute for present methods the rating of steam-generating units as a whole or in part in kilotherms per hour: heat-absorbing surfaces in kilotherms per hour per square foot, and furnaces in kilotherms per hour per square foot of grate or per cubic foot of volume. The use of the kilotherm and furnace factor is illustrated.

THAT the adoption of the Centennial method of rating boilers in horsepower was a serious mistake, has been apparent to engineers for many years. This feeling has grown rapidly of late, and there now seems to be an almost unanimous demand for a change. The only reason such a change has not been made is because thus far no satisfactory substitute has been suggested.

Most engineers and manufacturers have practically eliminated the term "boiler horsepower" from their vocabulary, though far too many still persist in using the equally misleading term "per cent of rating." For ten years neither of the authors of this paper has based any of his calculations upon either of these terms except when the public could not understand the omission. They have plotted boiler performances against B.t.u. per hour, evaporation, combustion rate, kilowatts, and in one case against pounds of sugar melted. In all cases the curves were more accurately interpreted than when plotted against horsepower or per cent of rating, but the terms used were not universal but applied only to a particular industry. All terms used in the last analysis must be based on the British thermal unit, for we are concerned with heat quantities, consequently many engineers are advocating a multiple of B.t.u. absorbed per hr. per sq. ft. of surface as a standard of boiler performance. Such a suggestion is fundamentally sound, but the authors have found that such a unit is not only inconvenient but is of little value for painting mental pictures of boiler performance.

Obstacles to New Methods of Rating

We believe that there are two fundamental obstacles that must be cleared away before any new term can be adopted. This paper is therefore offered primarily to stimulate discussion in the hope that the authors' suggestions may help clear the atmosphere and ultimately lead to the adoption of scientifically sound units which will also be in such a form that they will become popular by their ease of application.

The mistake that the Centennial committee made was in assuming that the boiler was necessarily an adjunct of the steam engine, and that little improvement in steam-engine economy could be expected. Horsepower rating was at that time of real value because it made easy the selection of boiler sizes to supply engines of known capacity. The use of steam for other purposes than power production soon made the term less valuable. Improvement in combustion rates forced upon us the term "per cent of rating," which was of great help between the years 1910 to 1917 because the distribution of boiler surface was fairly uniform and because large stokers had not become common. That time has passed and "per cent of rating" is now so misleading that it is valueless. The advent of superheaters, economizers, water walls, and air heaters has added to the hopeless confusion.

The principal difficulty in the development of a new term is due to the careless use of the word "boiler." Strictly this should refer to the shell only, but popularly it is made to include furnace, superheater, economizer, etc. A new definition of the word would be of little value, because a generation would pass before the old practice in the use of the word could be eliminated. It is better to supersede it as commonly used by another term.

"Steam Generator" as Definition of Modern Boiler Installation

Although one manufacturer has already used the term "steam generator" as representing a particular combination of boiler, furnace, etc., the expression is not new with him and is therefore public property. It accurately describes the modern boiler installation. We therefore suggest its adoption and offer the following definition:

> Steam Generator. An apparatus for the transformation of heat energy from its commercial form to the heat energy of the steam delivered by the apparatus.

This would mean that the steam generator of a modern boiler plant would consist, for example, of stoker, setting, water walls, boiler shell, superheater, economizer, and air heater. In other words, everything from the stoker hopper to the entrance of the breeching, and from feed valves to the boiler stop valve. An electric boiler would become an electric steam generator, including water tank and heating element.

The authors offer "steam generator" but hope that a simpler and distinctive term can be suggested. The name is unimportant so long as the word boiler is not used.

Since "boiler efficiency" has been so loosely used, we suggest the substitution of the term "gross steam-generating efficiency" for "combined boiler and furnace efficiency." We have included the word "gross" because we recognize the demand of many for a definition of the term "net efficiency," that is, an efficiency which has been corrected for the power expended for draft, feed, etc. We have made no attempt to define "net efficiency," as there are so many variables entering into its determination. It is a definition that may require some compromises, and hence must be written by a committee with authority. It is, however, very important that at least an approximate definition be adopted shortly.

With the adoption of the term "steam generator" or an equivalent, the most important step will have been taken toward a logical and useful method of rating these units. Most of the present confusion is now due to the misinterpretation of the word "boiler"—its common interpretation includes so many other types of apparatus. Let us therefore restrict the word "boiler" to include only the shell, or as an alternative to include superheater, economizer, and water walls, that is, all surface with gas on one side and water or steam on the other. The authors believe that the first is preferable, for to include the economizer with the boiler introduces the commercial objections that may be made by the manufacturer of one that does not manufacture the other. The definition of boiler does not affect the suggested method of rating.

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The ideal term for rating generating units should, if possible, be equally applicable to all sections of such units. The B.t.u. is the fundamental unit but is so small that for convenience in calculation it must be grouped in multiples. This problem is to adopt a convenient multiple of B.t.u. and a suitable name.

Problem of Furnace Rating

The problem of furnace rating is the other difficulty and appears to be more complicated, for it has been the chief stumbling block. A pound of coal is never a pound of fuel, hence the furnace is a highly complicated chemical manufacturing plant producing hot gases which cannot be accurately weighed nor can the initial temperature be measured with sufficient accuracy. It is impossible to adequately compare furnace performance on a B.t.u. basis because of varying coal analyses, the behavior of the ash alone being a limitation which is not indicated by "B.t.u. per pound."

The capacity of a steam-generating unit is limited not by the extent or arrangement of its surfaces nor by the square feet of grate or cubic feet of furnace volume, but by the heat per pound and weight of gas that is delivered to those surfaces. If we could accurately measure the weight or volume of gas and its temperature our problem would be simple. As conditions are now, in estimating performance we calculate the gas weights and theoretical temperatures, and assume by wide experience those corrections necessary for an estimate. The fuel analysis is *assumed*, a carbon loss is *assumed*, a percentage of excess air is *assumed*, a radiation and unaccounted-for loss is *assumed*, and if these assumptions prove to be correct, the forecasted steam-generating performance is obtained. If one assumption is far out of the way the guaranteed performance is not obtained unless the manufacturer has been able to include a wide margin of safety in his guarantees. The skilled estimator is consequently able to guess at performances with almost the degree of accuracy of his detailed estimates.

The purchaser will not agree to tolerances in measurement in the contract, but unwittingly accepts them when tests are made after erection. The fuel analysis or excess air may not be the same as stated in the contract, and unless the performance is very wide of the expectation he accepts the apparatus, deluding himself into believing that the difference in fuel analysis is probably the cause of the failure to meet guarantees when another false assumption may be the true cause.

At present when boiler shell and furnace are bought separately the purchaser "assumes all risk" whether he recognizes the fact or not, and we do not blame the manufacturers when each of them endeavors to fix the responsibility on the other.

The manufacturers of boilers, superheaters, and economizers can guarantee their equipment within the limit of error of available instruments if the purchaser states the weight of gas per hour and the temperature or heat content of the gas, and the purchaser can fairly hold the manufacturer to such a contract.

The stoker manufacturer can guarantee the percentage of carbon lost in the ashpit and the excess air necessary. For pulverized coal the percentage of excess air and carbon loss can be guaranteed within reasonable limitations.

It would seem, therefore, that if we can find a satisfactory method of measuring gas weights and heat content, such a method might be used as a basis for rating all apparatus comprising a steam-generating unit.

What has seemed to be an insurmountable obstacle has been the number of variable factors entering into such calculation and the difficulties encountered in measuring gas temperatures. Furnace gases are not uniform in temperature or chemical analysis, and gas-passage areas are so large that it is impossible to get better than an approximation of furnace temperature or heat content. Of all gas measurements, the analysis is probably the most easily obtained with reasonable accuracy. Fuel weights are readily obtained. The loss of carbon to the ashpit can be accurately determined when properly sampled.[3] The loss of carbon to the stack is now grouped with the unaccounted-for losses. With these data the weight of gas and heat imparted thereto can be determined with reasonable accuracy. The heat absorbed by the water can also be accurately determined, though some slight inaccuracies still exist in air-heater measurements; but inasmuch as that is so small a part of the whole generating unit, the accuracy of the whole is not greatly affected.

The output of the furnace and the absorption by the water and steam can be measured with an error only of that now included in "radiation and unaccounted for." The principal objection to such analysis has been the necessity of complicated calculations.

When fuel or gas analyses have not been available, estimates

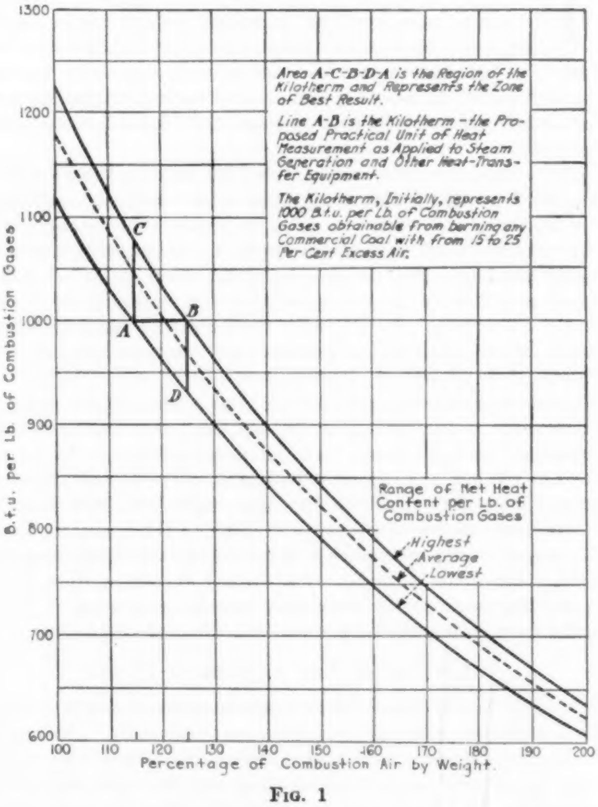

Fig. 1

are often made of gas weights by multiplying the B.t.u. per pound of fuel by some factor and adding an assumed excess air. For example, the factors given in Gebhardt.[4] It is interesting to note that for *all* fuels the factor used varies from 7.4 to 7.8, but that for any *class* of fuel the factor is constant within the limit of instrument accuracy.

Prof. H. L. Parr of Columbia University has shown that if the velocity pressure and temperature of the products of combustion are known, the B.t.u. per square foot of gas-passage area per second equals the product of a constant and the rise in temperature and the square root of the quotient of velocity pressure divided by the absolute temperature.

[3] The authors admit that this is a difficult task at times, but if extreme accuracy is required the entire refuse can be crushed and sampled.

[4] "Steam Power-Plant Engineering," Gebhardt, Table 12, p. 80.

HEAT CONTENT OF COMBUSTION GASES OF COMMERCIAL FUELS

In a paper presented before the American Boiler Manufacturers Association in 1925, Mr. Jacobi included combustion calculations of substantially all commercial fuels with varying percentages of air. With the exception of producer gas these calculations show that with 20 per cent excess air the formation of the resulting gas is accompanied by a heat liberation of approximately 1000 B.t.u. per lb. the highest being for fuel oil with 1040 B.t.u. and the lowest for low-grade lignite with 956, that is, a maximum range of less than five per cent. (Evidence of this may be seen in Fig. 1.)

The fortunate combination of a convenient multiple of B.t.u. and unusually good combustion conditions for coal furnaces, suggests the possibility of using this as a basis for rating both boilers and furnaces and the name "kilotherm" as representing one thousand (kilo) British *thermal* units. One thousand kilotherms would therefore represent 1000 lb. of gas each containing 1000 B.t.u. The absorption of 1,000,000 B.t.u. per hour by the boiler would represent the absorption of 1000 kilotherms per hour.

Since furnace conditions vary so widely, some modifying factor must be used with the kilotherm. Calling this the furnace factor it would represent the ratio of the actual heat content to one thousand. An average coal burned with 35 per cent excess air would deliver about 900 B.t.u. per pound of gas. The furnace factor would then be nine-tenths or 90 per cent. Fuel oil might be burned with a furnace factor of 110 per cent, and so on. The expression "900 kilotherms per hour at 90 per cent furnace factor" would be interpreted as 1000 lb. of gas per hour, each containing 900 B.t.u., and would give an accurate picture of furnace conditions. This would make it unnecessary to include any statement as to quality of the fuel or the class to which it belonged.

PROPOSED RATING OF STEAM-GENERATING UNITS IN KILOTHERMS PER HOUR

The authors therefore suggest the rating of steam-generating units as a whole or in any part in kilotherms per hour, heat-absorbing surfaces in kilotherms per hour per square foot, and furnaces in kilotherms per hour per square foot of grate or cubic foot of furnace, with the furnace factor stated in percentage.

Because of the tendency toward heating feedwater with bled steam, it is more convenient to rate turbine performance in B.t.u. per kw-hr. The conversion to kilotherms is merely that of moving the decimal point three places to the left. To illustrate the convenience of this term, an example is worked out in the Appendix. From this example convenience of the term should be obvious.

In offering these terms we are not offering any new unit except the furnace factor, and that is only a convenient method of indicating furnace conditions. It will take some time to accustom ourselves to its use, but it will give us a definite standard of comparison. Boiler-performance curves plotted for unity furnace factor will be the same for all commercial fuels, and curves for other furnaces will be equally useful. Instead of per cent of rating we can use kilotherms per hour per sq. ft.; 10 kth. per hr. per sq. ft. is the equivalent of 298 per cent of rating. Types of furnace construction can be rated with various kth. per hr. per cu. ft., depending upon the furnace factor. For example, a furnace found successful with coal for rates of 20 kth. per hr. per cu. ft. at 90 per cent furnace factor will be successful for oil *at the same factor*, but oil will be burned at a higher factor because lower excess air is possible. This difference in furnace factors immediately warns the purchaser that the oil-furnace temperature is higher and that the coal experience may not be of value in oil practice.

Considerable misunderstanding now exists in the design of furnaces for pulverized coal, although this was very ably discussed at the December, 1927, Meeting of the A.S.M.E., by E. G. Bailey who called attention to the fact that excess air and fusing point determine the possible rate of combustion. This might be restated in terms of fusing temperature and furnace factor with equal accuracy.

The maximum rate of combustion for stokers varies with the type of coal, the percentage of ash and the fusing temperature being the limiting factors. A furnace factor will indicate the excess air for such combustion. The limiting rates of any stoker could be stated accurately for any type of ash by stating the furnace factor.

The adoption of these terms will not eliminate the necessity of detailed accurate calculations for research or test work, nor will it eliminate the use of the Orsat apparatus or thermometer. It will permit commercial comparisons of apparatus with reasonable accuracy, and will make possible comparable scales in operating instruments. For example, the CO_2 meter may be calibrated in furnace factors and the flow meter and draft gage in kilotherms per hour, and the ratio of kilowatt-hours to kilotherms per hour in any one plant will be so nearly constant that the load indicators may be calibrated in kilotherms per hour. The application of the term grows as we study it. We are in no way sacrificing accuracy when necessary, but are making approximations more accurate and convenient.

Appendix

RECOMMENDATIONS

Confine boiler to boiler shell.

Abandon combination of boiler and efficiency in any form.

Substitute steam generators for combination of furnace boiler economizer, etc.

Substitute steam-generating efficiency for combined efficiency of boiler and furnace, etc.

Rate all steam-generating equipment as a whole or in individual parts in kilotherms per hour total or per sq. ft. of surface, sq. ft. of grate, or cu. ft. of furnace volume.

State furnace conditions by furnace factor in percentage.

DEFINITIONS

Kilotherm: 1000 B.t.u.

Turbine Kilotherm: The absorption of 1000 B.t.u. to produce mechanical or electrical power.

Boiler Kilotherm: The absorption of 1000 B.t.u. by water or steam.

Furnace Kilotherm: The delivery of 1000 B.t.u. to the products of combustion.

Furnace Factor: The ratio of the actual B.t.u. delivered to the products of combustion to 1000 B.t.u.

CALCULATION OF FURNACE FACTOR

$$\text{Furnace Factor} = ff = \frac{\text{B.t.u. per lb. fuel as fired} \times (1 - C - RU)}{\text{Wt. of gas per lb. fuel} \times 1000}$$

in which C = carbon loss that can be measured, in decimals
RU = radiation and unaccounted for.

These can seldom be separated and if large there is generally a carbon loss to the stack or a gross inaccuracy in test.

Weight of gas per lb. of fuel = G

$$G = \frac{11CO_2 + 8O_2 + 7\,(N + CO)}{3\,(CO_2 + CO)} \times \left(C_1 + \frac{S}{1.833}\right)(1 + \%\ \text{water})$$

$$= Y\left(C_1 + \frac{S}{1.833}\right)$$

C_1 = carbon consumed = $1 - C - RU$ within a reasonable degree of accuracy.

For operating comparisons and for any comparisons when basic data are assumed, weight of gas per lb. fuel =

$$G = \frac{\text{B.t.u. per lb. fuel}}{10{,}000} \times 7.5^{*} \times (1 + \%\ \text{excess air}) + C_1$$

B.t.u. required by turbine = T kth. per hr. × 1000.

B.t.u. delivered by steam generator = T kth. per hr. = B.t.u. absorbed by steam generator.

B.t.u. in gases entering heating surface

$$= \frac{T\ \text{kth. per hr.} \times 1000}{\text{Efficiency}}$$

$$\text{Weight of gases} = \frac{T\ \text{kth. per hr.}}{\text{Effy.}} \times \frac{1}{ff}$$

Efficiency =

$1 - H - St - CO - M - C - RU$

Let $X = 1 - H - St - CO - M$

Then efficiency $= 1 - X - C - RU$

in which H = hydrogen loss
St = stack (dry gas) loss
CO = CO loss
M = moisture loss
C = carbon loss
RU = radiation and unaccounted-for loss

$$\text{Total wt. of gases} = \frac{T\ \text{kth.}}{(1 - X - C - RU)} \times \frac{Y\left(C_1 + \dfrac{S}{1.833}\right) \times 1000}{\text{B.t.u.} \times (1 - C - RU)}$$

$$= \frac{\text{Turbine B.t.u.}}{(1 - X - C - RU)} \times \frac{Y\left(C_0 \times (1 - C - RU) + \dfrac{S}{1.833}\right)}{\text{B.t.u.} \times (1 - C - RU)}$$

in which C_0 = carbon by analysis.

The accuracy is affected only by this percentage of S. Since this is not generally considered in approximate or operating comparisons, $(1 - C - RU)$ cancels out, hence this furnace factor is a satisfactory one for comparisons. For extreme accuracy it would not be used because unnecessary.

Method of Using Kilotherm and Furnace Factor

Design Data. Kilowatts load, 10,000. B.t.u. per kw-hr. (256 deg. fahr. feed), 12,000. Bituminous coal, 13,500 B.t.u. Furnace factor = 0.8 (33.5 per cent excess air). Efficiency of steam generation, 78 per cent.

Kilotherms Absorbed (and Delivered) by Generator = 10,000 × 12,000/1000 = 120,000 kth. per hr. At 10 kth. per hr. per sq. ft. (298 per cent of rating), 14-high exit temperature of 700 deg. fahr. and reduction to 420 deg., an efficiency of 78 per cent can be obtained.

Kilotherms Delivered by Furnace = 120,000/0.78 = 154,000 kth. per hr.

Total Weight of Gas = 154,000/0.8 = 193,000 lb. per hr.

Economizer (or air heater) must cool 193,000 lb. per hour from 700 deg. to 420 deg. (Sufficient information for design.)

Fuel No. and (B.t.u. per lb.)		Values	Per cent of combustion air 100	120	140	160	180	200
3 (10900)	a	Lb. air	8.4	10.1	11.77	13.45	15.15	16.8
	b	Lb. combustion gases	9.3	11.0	12.7	14.35	16.05	17.7
	c	Cu. ft. comb. gases	110	132	154	176	198	220
	d	B.t.u. per lb. comb. gases	1180	1000	865	765	685	620
	e	B.t.u. per cu. ft. comb. gases	100	83.3	71.5	62.5	55.5	49.7
4 (12735)	a	Lb. air	9.7	11.65	13.6	15.5	17.5	19.4
	b	Lb. combustion gases	10.6	12.55	14.5	16.4	18.4	20.3
	c	Cu. ft. comb. gases	127	152.5	178	203	229	254
	d	B.t.u. per lb. comb. gases	1200	1012	875	775	670	625
	e	B.t.u. per cu. ft. comb. gases	100	83.5	71.4	62.5	55.5	50
5 (13700)	a	Lb. air	10.3	12.35	14.4	16.5	18.5	20.6
	b	Lb. combustion gases	11.22	13.27	15.32	17.42	19.42	21.52
	c	Cu. ft. comb. gases	135	162	189	216	243	270
	d	B.t.u. per lb. comb. gases	1220	1035	894	786	705	637
	e	B.t.u. per cu. ft. comb. gases	102	84.5	72.5	63.5	56.5	50.8
6 (14100)	a	Lb. air	10.8	12.95	15.1	17.3	19.5	21.6
	b	Lb. combustion gases	11.7	13.85	16.0	18.2	20.4	22.5
	c	Cu. ft. comb. gases	141.5	170	198	226	254	283
	d	B.t.u. per lb. comb. gases	1205	1015	878	772	690	625
	e	B.t.u. per cu. ft. comb. gases	99.5	83	71	62.5	55.5	49.8
7 (14700)	a	Lb. air	11.2	13.45	15.7	17.9	20.2	22.4
	b	Lb. combustion gases	12.15	14.4	16.65	18.85	21.15	23.35
	c	Cu. ft. comb. gases	146.5	175.8	205	234	264	293
	d	B.t.u. per lb. comb. gases	1210	1020	885	780	695	630
	e	B.t.u. per cu. ft. comb. gases	100	83.5	71.7	63	55.7	50
8 (12500)	a	Lb. air	9.6	11.52	13.45	15.36	17.30	19.2
	b	Lb. combustion gases	10.45	12.37	14.3	16.4	18.15	20.05
	c	Cu. ft. comb. gases	125.5	151	176	201	226	251
	d	B.t.u. per lb. comb. gases	1200	1010	875	763	675	625
	e	B.t.u. per cu. ft. comb. gases	99.5	83	71	62.4	55.5	49.8
9 (18600)	a	Lb. air	14.1	16.9	19.75	22.55	25.4	28.2
	b	Lb. combustion gases	15	17.9	20.75	23.55	26.4	29.2
	c	Cu. ft. comb. gases	184.5	221.5	258	295	332	369
	d	B.t.u. per lb. comb. gases	1240	1040	895	790	705	637
	e	B.t.u. per cu. ft. comb. gases	101	84	72.4	63	56	50.5
10 (21300)	a	Lb. air	17	20.4	23.8	27.2	30.6	34
	b	Lb. combustion gases	18	21.4	24.8	28.2	31.6	35
	c	Cu. ft. comb. gases	223	268	312	357	401	446
	d	B.t.u. per lb. comb. gases	1185	995	858	755	675	608
	e	B.t.u. per cu. ft. comb. gases	95.5	79.5	68.3	59.7	53	47.7

COMPOSITION OF TYPICAL COMMERCIAL FUELS (AS RECEIVED OR AS FIRED) THEIR HEATING VALUE AND THEORETICAL (100 PER CENT) AIR REQUIREMENTS FOR THEIR COMBUSTION

Fuel No.	Kind of fuel	Percentage composition C	H	O	S	Ash	Per cent moisture	B.t.u. per lb. as fired	100 per cent air per lb. of fuel as fired (at 60 deg. fahr.) Lb.	Cu. ft.
1	Low-grade lignite	39.4	6.8	43.8	0.7	9.3	36.2	6,600	5.0	65.5
2	High-grade lignite	57.8	6.0	31.0	0.4	4.8	20.7	9,940	7.5	98.0
3	Low-grade bituminous	60.9	5.8	19.2	3.7	10.4	12.7	10,990	8.4	110.0
4	Medium-grade bituminous	70.5	5.4	11.2	2.9	10.0	5.2	12,735	9.7	127.0
5	High-grade bituminous	75.7	5.4	10.3	1.2	7.4	3.5	13,700	10.3	135.0
6	Low-grade semi-bituminous	80.7	4.3	3.2	1.4	10.4	1.2	14,096	10.8	141.5
7	High-grade semi-bituminous	84.3	4.7	5.2	0.7	5.1	3.1	14,688	11.2	146.5
8	Avg. anthracite	75.2	2.8	4.1	0.8	17.1	2.1	12,472	9.6	125.5
9	Avg. fuel oil	86.7	11.6	0.5	1.0	0.0	1.0	18,570	14.1	184.5
10	Natural gas.... $98.2\,CH_4 + 0.1\,C_6H_6 + 0.25\,CO + 0.25\,O_2$							21,300	17.0	223.0
11	Avg. coke-oven gas $6CO + 42H_2 + 34.3CH_4 + 2C_2H_4 + 2C_6H_6 + 1.1O_2 + 2.6CO_2 + 10N$							14,384	11.35	149.0
12	Avg. producer gas $14.34CO + 2.8H_2 + 5.56CH_4 + 0.1O_2 + 10.5CO_2 + 66.7N_2$							1,397	0.92	12.1

HEAT CONTENT AND QUANTITY OF GASES RESULTING FROM THE COMBUSTION OF TYPICAL COMMERCIAL FUELS WITH VARYING AMOUNT OF AIR SUPPLY

(Values plotted in Fig. 1)

Fuel No. and (B.t.u. per ib.)		Values	Combustion air, per cent 100	120	140	160	180	200
1 (6600)	a	Lb. air	5.0	6.0	7.0	8.0	9.0	10.0
	b	Lb. comb. gases	5.9	6.9	7.9	8.9	9.9	10.9
	c	Cu. ft. comb. gases	65.5	78.7	91.8	105.0	118.0	131.0
	d	B.t.u. per lb. comb. gases	1120	956	835	742	666	605
	e	B.t.u. per cu. ft. comb. gases	101	84	72	63	56	50
2 (9940)	a	Lb. air	7.50	9.00	10.50	12.00	13.50	15
	b	Lb. comb. gases	8.45	9.95	11.45	12.95	14.45	15.95
	c	Cu. ft. comb. gases	98	117.7	137.4	157	176.5	196
	d	B.t.u. per lb. comb. gases	1180	1000	870	768	688	623
	e	B.t.u. per cu. ft. comb. gases	101.5	85.2	72.3	63.4	56.4	50.7

Induced-Draft Fans: Cu. ft. per min. $= \left(120{,}000 \times \dfrac{1}{0.78} \times \dfrac{1}{0.8}\right) \times \dfrac{1}{60} \times \dfrac{1}{\text{density}}$

Forced-Draft Fans: Cu. ft. per min. =

$$\frac{193{,}000 = (\text{total coal per hr.} \times \text{per cent combustible})}{60 \times \text{density}}$$

Total Coal per Hour $= 120{,}000 \times \dfrac{1}{0.78} \times \dfrac{1}{13{,}500}$

Cubic Feet of Furnace $= \dfrac{120{,}000}{0.78} \times \dfrac{1}{\text{desired B.t.u. release}}$

Square Feet of Grate $= \dfrac{120{,}000}{0.78} \times \dfrac{1}{\text{combustion rate}}$

* Varies from 7.4 to 7.8; uniform for any class.

$$\textit{Reduction in Temperature by Water Walls} = \frac{(\text{B.t.u. absorbed by water walls}) \times ff}{\text{Specific heat} \times \text{kth. per hr.}}$$

$$\textit{Water Weight} = \frac{\text{kth. per hr.} \times 1000}{\text{Total heat of steam} - \text{total heat of feed}}$$

PROF. H. L. PARR'S COMBUSTION FORMULA FOR B.t.u. IN FLUE GASES PER SQ. FT. OF FLUE SECTION PER SECOND ABOVE SOME TEMPERATURE t_1 DEG. FAHR. OR T_1 DEG. FAHR. ABS.

$$\text{B.t.u. per sq. ft. per sec.} = V \times A \times \delta_2 \times C_p \times (t_2 - t_1)$$

in which V = velocity of gas in ft. per sec.

A = area of flue = 1 sq. ft.

C_p = specific heat at constant pressure

δ_2 = lb. per cu. ft. at $t_2 = \delta_0$ (at 32 deg.) $\times \dfrac{T_0}{T_2}$

t_2 = temperature of gas

$V = \sqrt{2gH}$, in which H = vel. head in ft. of gas

$= \sqrt{2g\dfrac{P}{\delta_2}}$, in which P = vel. pressure.

$$(\text{B.t.u. per sq. ft. per sec.})^2 = 2g\frac{P}{\delta_2} \times \delta_2^2 \times C_p^2 \times (t_2 - t_1)^2$$
$$= 2g\,P \times \delta_2 \times C_p^2 \times (t_2 - t_1)^2$$

But $\delta_2 = \delta_0 \dfrac{T_0}{T_2}$

$$\therefore (\text{B.t.u. per sq. ft. per sec.})^2 = 2gP \times \delta_0 \times C_p^2 \times \frac{T_0}{T_2}(t_2 - t_1)^2$$

Gas	C_p	C_p^2	δ_0	$C_p^2 \times \delta_0$
Air	0.24	0.0576	0.0807	0.00464
CO_2	0.20	0.0400	0.1234	0.00494
CO	0.24	0.0576	0.0780	0.00448
H	3.4	11.5600	0.0056	0.00648
O	0.23	0.0529	0.0890	0.00462
N	0.25	0.0625	0.0780	0.00487

$C_p^2 \times \delta$ is so small a quantity that it will affect the accuracy of the results less than the probable error in measuring t_2 or P, and except in the case of H may be taken as a constant K.
Hence

$$(\text{B.t.u. per sq. ft. per sec.})^2 = 2g \times P \times K \times \frac{T_0}{T_2} \times (t_2 - t_1)^2$$

in which $2g$, K, and T_0 are constants, and B.t.u. per sq. ft. per sec. = Constant $\times \sqrt{\dfrac{P}{T_2}} \times (t_2 - t_1)$

Discusssion

IT IS not intended at this time to give more than a general outline of the discussion provoked by the paper by Shoudy and Jacobi. Numerous written discussions from men fully qualified to express opinions were presented and others have since been received. It is possible that at a later date some or all of these may be published.

The general tone of the discussions was sympathetic to the idea put forth by the authors that a revision of engineering terminology as applied to boiler capacity and performance is desirable although complete agreement with the manner in which it should be accomplished and with the terms suggested in the paper was, of course, lacking.

Considerable attention was devoted to definition of the structural elements entering into the boiler plant. The terms "boiler" "steam generating unit," and what they should comprise were variously interpreted, showing that in this fundamental aspect of the problem unanimity of thought is yet to be obtained.

It was pointed out that there might exist an undesirable confusion of meaning if the authors' term "kilotherm" were to be adopted, inasmuch as the gas industry of Great Britain uses a unit, the "therm," which is defined by Parliament as equivalent to 100,000 B.t.u., while the authors' "kilotherm" is 1000 B.t.u. The term "kilber" was suggested as one possible alternative, and "Rumford" as an other.

"Furnace factor" is a new term and its reception varied from approval to doubt as to its desirability. Thinking in terms of excess air would, it was said, make "furnace factor" unnecessary, and the opinion was expressed that no new terms which do not go beyond the simple ones we now have should be adopted, as with the advance of knowledge, combustion is seen to include more and more factors, some of which are not included in the authors' "furnace factor."

That the efficiency of the entire boiler plant is a first consideration was the view of one discusser who suggested the following terms: (1) the efficiency of heat generation, applied to the furnace and grate and called as now "furnace efficiency;" (2) the efficiency of heat absorption, applied to shell, water walls, superheater, and low-temperature element, called absorption efficiency; and (3) the efficiency of heat recovery, applied to the economizer and preheater, called the "recovery efficiency." All of these efficiencies combine to give the "plant efficiency."

McWane Method of Making Cast-Iron Pipe

THIS method has been put into operation at one of the Birmingham, Ala., foundries of the McWane Cast Iron Pipe Co.

The new process retains the McWane feature of casting pipe 4 in. and larger in 16-ft. lengths horizontally in green-sand molds with green-sand cores.

The layout of the new foundry unit is interesting mainly in that it permits continuous operation of all factors used in this mechanical process of making pipe. Instead of a certain number of molds being prepared and the molten iron subsequently poured into them, ramming, core making, core setting, pouring, shaking out, core-bar pulling, and the return of the flasks, sand, and core bars for immediate reuse are simultaneous operations.

Perhaps the most outstanding feature of this new process is that, instead of a certain division of classes and sizes of pipe-making equipment arbitrarily fixing the relative output of each day's work, the entire mechanical unit of the McWane plant runs on a given size, as in the case of a rolling mill. Thus orders—and not the proportion of plant equipment for given sizes of pipe—determine the scheduling of production.

Molding sand used in the McWane mechanical process is handled entirely by conveyor equipment. After the sand leaves the shake-out machines, it is carried to reconditioning equipment consisting of screen, pug mill, blender, storage bins, and conditioner. Then a belt conveyor, which runs underground to the foundry, returns it to service bins above and behind jolt rammers.

When a mold is placed at a rammer, the sand is discharged directly into it. Then comes the jolt-ramming operation, which is finished off with manual pneumatic rammers. Any surplus sand that may have been discharged on to the rammer from the service bin is shoveled on to floor gratings immediately in front of the rammer. From there it falls to a clean-up conveying system beneath the floor of the foundry, and is in this manner restored to service.

The output of each mold is from one to six 16-ft. lengths of pipe, depending upon the pipe diameter. All the equipment in this unit of the McWane plant is designed to make pipe from 4 to 12 in. in diameter.

Multiple-lip ladles are employed entirely. Each of these ladles is equipped with 14 spouts and is capable of pouring two 6-in. or two 8-in. pipes at the same time. As previously stated, the number of lengths of pipe to a mold varies with the size being cast.—*The Iron Age*, vol. 121, no. 15, Apr. 12, 1928, pp. 999–1003, 6 figs.

Education and Training as Applied to the Engineer

Particulars of the Continuation Arrangement Existing Between the University of Pittsburgh And the Westinghouse Electric and Manufacturing Company

By F. L. Bishop,[1] Pittsburgh, Pa.

As the author sees it, the two important problems confronting engineering education today are:

1 The continuation of the young man's education in the immediate years after leaving college when he is going through the process of orienting himself to his profession.

2 The selection, preparation, and development of the younger teachers in the engineering schools.

The engineering schools originally devoted their entire energies to preparing young men to enter the fields of design, research, etc., but as the country developed and industry became more complex, an ever-increasing number were to be found in management, in operation, and in distribution, with the result that grave questions arose as to whether the education and the training which prepared a man to become a designing engineer was the best in every way for the man who would eventually become an executive in industry. In other words, the economic and the human factors became more and more pressing, and the demand on the engineering colleges was for more economics and for less design. If a young man is to make progress in any one of these fields he finds that he must supplement to a very marked degree the work which he takes as an undergraduate. If he is in design, or strictly engineering so-called, he finds the need possibly of more mathematics, of certain specialized fields in physics, of physical chemistry, etc. If he gets into the distribution field he finds that while he probably has had a good fundamental course in economics, he lacks the broad grasp together with high specialization which is essential in this field. He may need to know more of banking, of domestic and foreign commerce, accounting, and the numerous allied fields.

The University of Pittsburgh-Westinghouse Graduate Arrangement

As an illustration of the organized effort to provide such graduate work, the author will describe in some detail the arrangement existing between University of Pittsburgh and the Westinghouse Electric and Manufacturing Company.

This arrangement began in February, 1927, consequently students have been registered in it for three semesters. In all, 117 different graduate students have taken advantage of this opportunity, and 40 of these entered with advanced standing, having done graduate work either at the University of Pittsburgh or at some other institution previous to their registration. Courses which they are taking at the University include differential equations, mathematical physics, optics, etc. One innovation was made in February, 1928, when a class of seventeen was started in differential equations at Sharon under the direction of Prof. Karl D. Swartzel, who meets the class at Sharon rather than have them come to the University.

The University of Pittsburgh has for many years followed the cooperative plan in its School of Engineering. Heretofore the plan has applied to undergraduate work only. That the extension of this principle in engineering education to graduate work should receive its impetus at the University is more than a coincidence. It arises partly from the experience of the University in cooperative engineering education and partly from the fact of the University's location in an engineering center.

An agreement effected between the Westinghouse Electric and Manufacturing Company and the Graduate School of the University of Pittsburgh identifies certain features of the educational program of the Westinghouse Company with the Graduate School of the University of Pittsburgh. Certain Westinghouse engineers are given regular university appointments as lecturers in the Graduate School. This plan makes it possible for designated employees of the Westinghouse Company to register in the Graduate School and to receive resident university credit for work done within the walls of the industry under the guidance of practicing engineers, this work ultimately leading to the M.S., or Ph.D. degree.

Courses are open, except by special permission, only to designated employees of the Westinghouse Electric and Manufacturing Company who are graduates of accredited colleges or universities.

No student may take any of the Westinghouse courses for credit in the Graduate School unless he has in advance the approval of the Dean of the Graduate School and of the head of his major department.

Credits earned through the Westinghouse courses are recorded as resident credits. A minimum of twenty-four resident credits is required for any degree from the University, of which in this particular arrangement a minimum of nine must be earned upon the campus. The research work leading to a thesis may be conducted with the consent of the head of the department under the direction of any of the Westinghouse lecturers.

In addition to such organized efforts there are available in nearly all industrial centers graduate courses in practically every field of endeavor, so that the engineering graduate needs only the encouragement and desire to continue his work beyond his college years.

The Society for the Promotion of Engineering Education is preparing a plan to submit to the national engineering societies in which will be outlined the responsibility for the continuation of the education of the engineer when he finishes his college course. The pioneer societies such as the Institution of Civil Engineers in Great Britain support this idea by their original purposes and functions. The engineering colleges require the organized cooperation of the professional societies and industries. This organized group should function so as to advance the common interests of the colleges of engineering, the engineering profession, and the industries.

It would seem, then, that some progress is being made toward the solution of our first problem, i.e., the continuation of the education of the engineering graduates.

If the education of the young engineer can be extended beyond the time of graduation, the question naturally arises as to how we can use this fact to advantage in our undergraduate course. The answer is not so much in the modification of the

[1] Secretary, Society for the Promotion of Engineering Education.
Presented at the Spring Meeting, Pittsburgh, Pa., May 14 to 17, 1928, of The American Society of Mechanical Engineers. Abridged.

curriculum as in the selection, preparation, and training of the engineering teacher.

SELECTION, PREPARATION, AND DEVELOPMENT OF TEACHERS

Before going into a discussion of this question of teachers we should have definitely in our minds that the engineering college is an educational organization and not an engineering organization. Very often, too often in fact, the teaching staff are selected for their engineering abilities and not for their teaching qualifications. Assume that the teacher has been selected for his teaching ability. If he has a vision of achievement open to the engineer, and is a man of inspiration and magnetic personality, his students will see such a vision no matter what the subject be that this man teaches. It is also advantageous to have the student in actual contact with industrial leaders during a portion of his undergraduate course in order that he may see the great undertakings which have been accomplished in a given field and thus have a vision of the future of at least one industry.

Efforts to develop, broaden, and enrich engineering education will be largely unavailing unless teaching service is able to enlist and hold able and inspiring men. The present situation, as far as statistical data can reveal it, is marked by negative virtues rather than glaring defects. There is abundant evidence that increasing difficulty is being experienced in filling vacancies of the highest importance, that the more gifted younger men in teaching ranks are not being developed to the same degree as their equals in active life, and that the administrative heads of institutions have not yet given the same concern to attracting and holding men of high professional distinction to chairs of engineering that has been shown in certain other realms of professional education.

Prompt action should be taken to meet and offset the declining drawing power of the teaching career in engineering before a more critical situation arises. Recent years have greatly multiplied the opportunities afforded in engineering practice for human service and leadership of the broader kind, and for the attainment of high scientific distinction. Taken in conjunction with notably superior financial rewards, these conditions have tended to make a teaching career relatively less attractive to men of the type most desired for positions of leadership in education. A laissez-faire policy will not meet this situation.

Discussion

WRITTEN discussions of Dr. Bishop's paper were submitted by W. E. Wickenden, Director of Investigation, Society for the Promotion of Engineering, by A. A. Potter,[2] Dean of the Schools of Engineering of Purdue University, and by C. D. Billmyer[2] of the power department of the Atlas Portland Cement Co., Northampton, Pa. These are given below.

W. E. WICKENDEN. Dr. Bishop's paper outlines a form of local specialization in the more advanced areas of engineering education which the writer considers to be highly significant. In fact he believes it points the way for the most important steps yet to be taken on an extensive scale. Most of the betterments desired in engineering education will have to be sought by extending education more effectively into the after-college period.

There are good reasons why the work of the engineering colleges should be so much alike in the undergraduate period. There are equally good reasons why the more advanced work should be specialized by institutions, according to their environments. It is seldom possible for an undergraduate to have advance knowledge of his career, and a provisional choice between the major branches of engineering is the most that can be asked of him. Such a choice is not primarily an act of specialization but rather an insurance against scattering of effort. We have records which show that nearly two-thirds of the graduates remain permanently in the major branch followed in college, although not always in strictly technical pursuits. On the other hand, less than one-tenth of the graduates pursue careers for which some other type of education would have been more advantageous. On the face of the records there is no great warrant for condemning the usual plan of undergraduate work as excessively specialized. It is essentially a blanking-out process, and the detailed professional formation belongs to a later period, after the novice, by actual trial and contact, has gained some definite orientation to his career.

[2] Mem. A.S.M.E.

The training of an army officer is done on the same principle. West Point is for blanking-out purposes. The graduate, either by choice or according to his rating, passes into a definite arm of the service for a period of preliminary experience, then is detailed to a special graduate school for further training, repeating the process at intervals. A major in the Quartermaster's Corps informed the writer that of his first twenty years in service after West Point, four had been spent in such schools of specialization.

There can be little specialization among the undergraduate engineering colleges because of their peculiar function as human clearing houses. Of the 135 best-known engineering colleges in the United States, 70 are in small cities or villages in the open country and 65 are in urban centers, and not all of the latter have a real industrial environment. Practically half of the students and teachers are so placed that it is impossible to maintain an intimate contact with engineering and industrial activities. It is a striking fact that the engineering colleges in our three greatest industrial centers have relatively small enrolments. In the New York area, for example, the total enrolment is barely half in proportion to population of the average for the country at large, while in such strongly rural states as Iowa and Kansas the ratio greatly exceeds the general average. The census shows that our farm population produces twice as many children as can find careers in agriculture. The other half pass into commerce, industry, and the professions. More than half of our engineering colleges operate as clearing houses between rural origins and industrial careers. At best they can produce only a semi-fabricated product.

Under the conditions stated, we cannot expect to provide a more complete professional training by keeping the boys for a longer continuous period in the same college. A stage of migration and readjustment must intervene before truly specialized training can be given to good advantage. Satisfactory fundamental undergraduate training can be given in almost any location. Training for highly scientific research can be given wherever the guidance of master minds and the use of special facilities are available. Sound specialization for engineering practice needs a combination of master minds, special facilities, and special environment. Furthermore, it should be undertaken only after the young man has gained some experience and orientation. In most cases we cannot expect the novice engineer to leave his work and return to school as a full-time student. Unless he wishes a research training, it is doubtful whether such a method is most effective, since much of the special training he needs can be gained only in actual contact with reality.

The cooperative plan of education for undergraduates has well-recognized advantages, but it provides a combination of instruction and experience on a fairly rudimentary level, not extending into the area of true professional specialization. The possibilities of cooperative education for young engineers in practice are now being more widely recognized and developed. The General Electric Co. has arrangements of this general

nature with Union College and the Massachusetts Institute of Technology. For the last eight years the Bell Telephone Laboratories has had an arrangement with Columbia whereby selected research engineers may pursue work for graduate degrees. The plan outlined by Dr. Bishop is more elaborate. It marks a distinct forward step in formal recognition of the training given within industry proper. It is natural that this cooperative movement should first arise in the electrical industry, which is perhaps most aware of its dependence on advanced scientific knowledge and technique.

The principle, however, is of general significance and a wider adoption is to be expected. The possibility of improving and extending engineering education in the undergraduate period is inherently limited. The greatest advance in engineering education must come in the after-college period. Much of this later education cannot be given in the artifically simplified environment and regime of a school, and must be given within industry and engineering practice. The colleges, especially those in great engineering centers, must cooperate actively, working out a process of specialization by institutions. The professional societies should strongly encourage this advanced type of cooperative education, and, as opportunity offers, share in giving it due recognition. If we are to work out some orderly and recognized pattern of a preparatory discipline for the engineering profession, this type of education should have an important place in it.

A. A. Potter. Dr. Bishop in his paper focused our attention upon two important problems: post-graduate engineering study, and the importance of the teacher in any educational enterprise.

Commencement should mark the real beginning of the student days for those who are ambitious to succeed in any profession. A story is told of a middle-aged college graduate who upon meeting his professor of English expressed regret that the reading of the play of Macbeth had not been completed during his undergraduate days and added that he had been wondering for over twenty years how the story of Macbeth had ended.

Very few engineering-college graduates seem to realize that their intelligence as well as their physique keeps on growing only through exercise. Accordingly, many students sell their textbooks, discontinue their studies immediately after graduation, and cannot be differentiated from the non-college man five years after they had received their degrees.

The University of Pittsburgh and the Westinghouse Electric and Manufacturing Company are contributing to the welfare of large numbers of engineering-college graduates through their post-graduate cooperative engineering course which leads to advanced degrees. It is hoped that engineering colleges situated in other industrial centers will follow the example of the University of Pittsburgh for the benefit of the recent college graduates in their localities. It is an opportunity for service to the engineering profession and to industry in connection with which industry and the engineering college can cooperate most effectively.

In discussing teaching, Dr. Bishop calls attention to the danger of selecting teachers mainly for their engineering abilities. Practically every executive of a large engineering college has had sad experiences with teachers who were master-engineers but who lacked the ability to interest and to enthuse their students. The specifications for any teacher should include: power to stimulate intellectual curiosity in their students, ability to adjust their instruction to the comprehension of their students, capacity for growth, mastery of the teaching process, and knowledge of the subject. Master-teachers who possess these specifications should be given every encouragement to remain on the staffs of our engineering colleges. Industry has an opportunity to make teaching attractive to the best minds of the country if it will cooperate with the engineering colleges of this country as is the practice in the most progressive countries of Europe.

Finally, attention should be called to the fact that correct living, service to society, character, and good citizenship must be considered upon an equal basis with scholarship among the objectives of education as applied to the engineer of the United States of America.

C. D. Billmyer. To the writer, it seems that Dr. Bishop has very appropriately stressed the most pressing problems of engineering education, even though they are closely inter-dependent. In view of our rapidly changing conditions, the advisability of much specialization during the four-year undergraduate courses is very questionable. Contact with some of our technical school graduates often prompts the desire for less differentiation in our engineering courses and a deeper delving into the fundamental sciences in the hope of securing greater mental training at the expense of the less necessary acquisition of so much specialized information which is often of little use to the individual. This more effective mental discipline, maintained during the undergraduate years, will enable the majority of young men who for various reasons have not the opportunity to pursue advanced courses in residence at any institution, to continue their education from the mass of specialized literature rapidly becoming available.

A desire for a more thorough training during the undergraduate years and the ability to successfully continue it after graduation, can seldom be secured without the inspiration of teachers with the proper character and personality. The greatest weakness of some of our less effective institutions lies in the scarcity of the kind of teacher so well described by Dr. Bishop. It seems evident that the engineering profession should cooperate more actively with the teaching profession, in an effort to impress upon the proper educational authorities the need for seeking and holding the type of teacher referred to, and give these executives whatever aid is possible in securing the necessary funds without which little permanent benefit can be expected.

From the writer's personal experience as a teacher, he has formed the opinion that the cooperative method of engineering education is a decided improvement over our conventional courses, and can be brought to an even more successful conclusion by a more sympathetic attitude on the part of local industries. Here again, the engineering profession can give decided help.

Anhydrites in Cement Retardation

INFORMATION obtained so far from tests by the United States Bureau of Mines on the action of anhydrite as a retarder for Portland cement seems to justify the following conclusions:

It is practically essential that the clinker and retarder be ground together if consistent results are to be obtained in any investigation of this type

The type of anhydrite has no marked relation to its action as a retarder, but the fineness of the retarder is of considerable importance, particularly as regards its effect upon the plasticity of the cement

If the cement is properly retarded all forms of calcium sulphate will produce practically the same quality of cement

While cement of good quality has been obtained by using anhydrite as a retarder, the variation in the properties of the cement clinker itself makes it essential that information be obtained concerning the retarding action of calcium sulphate before stating definitely which form, if any, is the most efficient retarder for Portland cement clinker.

Evaporative Cooling

A Report of Tests Which Were Made to Compare the Performance of an Automobile Engine With Water and Evaporative Cooling Systems

By ALFRED H. MARSHALL,[1] HARTFORD, CONN.

IT IS interesting to note that probably the first system ever used for cooling internal-combustion motors was based on the evaporative principle. The cylinder was enclosed in a sort of hopper which was filled with water, and the heat of the cylinder walls was dissipated in producing steam. More water had to be added occasionally to make up for that evaporated. The cylinder itself was at all times completely surrounded by water. This principle of cooling by evaporating water at atmospheric pressure has become commonly known as "steam cooling," although the term "evaporative cooling" is more appropriate and is now coming into use.

A patent was taken out in 1900 on this very scheme by John Imbray of England. Since that time, thousands of farm engines have been built with the familiar hopper above the cylinder. It is the simplest system in which water is used, requiring only an occasional refilling of the hopper to replace the water evaporated. Furthermore, it has proved itself to be a satisfactory and efficient method of cooling stationary engines.

We can see, however, that this method as it stands is not readily adaptable to automobile engines where the loss of water by evaporation would necessitate stopping along the road for refilling. In order to use the steam cooling system on automobiles, provision must therefore be made to have a closed system with no resultant loss of water. If the radiator on the car is used as a steam condenser, and the condensate is returned to the water jacket, the same system results, provided there is a vent to the atmosphere. With this idea in mind, several engineers in the last few years have worked to develop systems which will operate efficiently and effectively.

The problem is not as simple as it sounds in the previous paragraph. If the condenser could be placed above the engine, the condensate could flow back by gravity into the engine jacket. This position of the condenser could not be used on automobiles, as it would greatly affect the appearance of the car. In order to have the condenser in the usual place of the radiator, the condensate must be returned to the jacket with some sort of pump. Samuel W. Rushmore[2] found that a positive pump was necessary to handle the hot condensate; the centrifugal pump being inefficient because its normal head, when operating with a condenser, is reduced by boiling, and by the low level of water in the condenser. Wellington W. Muir,[3] however, operates the system in such a way that the level of water in the radiator is always above the centrifugal pump, making the pump self-priming, with a consequent satisfactory operation.

It is sufficient to say that the systems developed by Rushmore and Muir, which are those with which the automobile industry is not familiar, have been perfected to such an extent that they will produce the same effect as the simple steam cooling system first described, without any loss of water. A description of these systems will be found with Figs. 1 and 2.

Advantages of Evaporative Cooling

What are the advantages to be derived from this steam cooling system and why is it better than the apparently successful water cooling system? The water-cooled engine is subject to "fevers and chills," and complicated thermostatic devices and shutters are being used to try to keep the cooling water at a uniform temperature of about 170 deg. fahr. Automobile engines operating with water cooling are subject to crankcase dilution. In order to prevent the water from reaching the boiling temperature in hot weather, it must be circulated at a high velocity through the

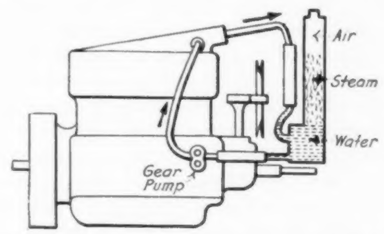

Fig. 1 Rushmore System of Evaporative Cooling

(The steam-water mixture from the outlet of the jacket should enter the condenser at the bottom. Then the steam, rising into this cooling space, will push out the air before it to the top of the condenser and out by the usual overflow vent. But the steam will rise only till it condenses; and the condensate will always return to the bottom header at boiler temperature. It is interesting to observe the small size of pump required to return the condensate to the jacket.)

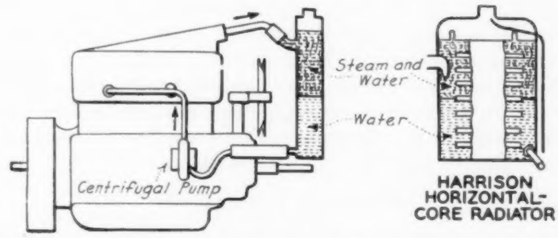

Fig. 2 Harrison (Muir) System of Evaporative Cooling

(The steam-water mixture is introduced at a point near the top of the radiator or condenser. The water drops immediately to the bottom through the passage provided, while the steam circulates from side to side through the horizontal cores. The condensate is withdrawn and returned to the jacket from an outlet on the side opposite the entering side of the radiator. The water level is allowed to rise to a point where the pump is self priming, and water will circulate through one-half of the radiator tubes, only one-half of the core being utilized as a condenser. A vent is provided at the top of the centrifugal pump to prevent its becoming steam bound.)

radiator. This results in a small difference of temperature between the inlet and outlet of the radiator, which means that the radiator is not an efficient heat exchanger.

In order to understand the cooling obtained with a steam cooling system, we must consider the thermodynamic action. Water does not circulate in the steam-cooled system. The heat required to raise the water from its initial temperature to the boiling point, 212 deg. fahr. is negligible compared with the actual heat produced by the engine which must be taken out by the cooling medium. It takes only one heat unit to raise each pound of water in the jacket one degree, and as there are very few pounds of water in the jacket, it takes very little time to bring the water to the boiling temperature, but to change each pound of water at 212 deg. into steam requires 971.7 heat units.

In the circulating system there is a rise of about 25 deg. in the cooling water in passing through the engine block, so that cooling obtained by boiling away one pound of water is equivalent to the

[1] Experimental Test Engineer, Pratt & Whitney Aircraft Co., Hartford, Conn.

[2] Rushmore Laboratory, Plainfield, N. J.

[3] Harrison Radiator Corp., Lockport, N. Y.

Graduating Thesis, Princeton University School of Engineering. Awarded Student Prize, 1927. Abridged.

cooling obtained by circulation of 39 lb. of water. This explanation shows how heat can be carried away by vaporizing water, and that cooling can be obtained despite the fact that the water temperature is practically constant at 212 deg.

There are several obvious advantages in the engine performance due to this higher operating temperature. One marked effect is that the engine will operate at a uniform temperature of cooling medium at 212 deg. in any climate provided the steam is condensed. This is a very decided improvement in itself over the water-cooled engine, one reason being the fact that this uniform temperature exists in all parts of the cylinder jacket, whereas, in the water-cooled motor, the velocity of the water in different passages—and therefore the temperature of the water, varies according to the design of those passages, and one cylinder may be overcooled while another is undercooled. It is obvious that the slight increase of temperature in the cooling medium from 185 to 212 deg. will not cause any of the metal parts to overheat, whereas that slight increase in temperature does materially lower the engine friction by making the lubricating oil less viscous. Steam cooling gives the advantage of a short warming-up period as there is less water in the system and it is not chilled in the radiator. However, one effect which might seem detrimental to using evaporative cooling is that the increase in temperature will lower the volumetric efficiency. A change, therefore, in the power output will depend upon whether the decrease in power due to the lowering of volumetric efficiency will be greater than, equal to, or less than the increase of power caused by the lowering in engine friction.

Other effects of steam cooling as compared with water cooling have had to be determined by experiment. S. W. Rushmore and A. Ludlow Clayden[4] have found that crankcase dilution is practically eliminated with the rapid warming up of the cylinder walls which prevents condensation of gasoline vapor and moisture when the mixture enters the cylinder. Some find that there is much less carbon accumulation when operating at a uniform temperature. There is no loss of alcohol when introduced into the cooling water to prevent its freezing in winter because it also is condensed in the condenser. Fuel economy has been found much higher in most all of the tests made.

Princeton Experiments

The purpose of the experiments made at Princeton was to make a fair comparison of water cooling and evaporating cooling systems with regard to the actual performance of each system as dissipators of heat, and also to study the effect of each system on the motor performance. We were also interested in temperatures reached in the engine itself, and in order to make comparisons, two of the hottest parts of the motor—the exhaust-valve seat and the exhaust gases, were chosen for the measurement of the temperatures. This gave examples of both metal temperatures and combustion-chamber temperatures.

The tests were made on a new Chevrolet motor after it had been "run in" for about 25 hours. The motor was set up on a stand, as shown in the illustrations, with the instrument board in the immediate and convenient vicinity of the engine. Although it is contrary to general rules of testing to use any form of friction brake for high-speed motors, the one used for the tests proved very satisfactory and gave good comparative results, which were wanted. It was a water-cooled brake originally designed for rope, but because the rope could not hold the load, brake lining was substituted and this was constantly supplied with oil. This remedied the effect of grabbing usually encountered when brake lining is employed to hold the load, and as a result the load was held quite steadily.

[4] Chief Engineer, Gas Engine Research, Sun Oil Company, Philadelphia, Pa.

The steam cooling system used on the test was that of Muir's; the radiator and fixtures being furnished through the kindness of the Harrison Radiator Corporation. It had the particular advantage that it could be quickly changed over to water cooling by simply filling the radiator with water. When operating as a steam cooling system, the radiator would be half-filled with water, the level in the radiator corresponding to the top of the cylinder head of the motor. Naturally only one-half the core was then used as a condenser, so in order to have real steam cooling, the quantity of cooling air passed through the radiator was varied according to the temperature desired in the water jacket. In this way it was possible to get steam cooling with water at 212 deg. from the outlet of the jacket at all speeds when the engine operated under full load. Unfortunately, the capacity of the fan was not great enough to supply sufficient air to keep the temperature of the water below boiling at the highest speeds when operating water-cooled runs on hot days. However, the fact that the steam cooling system worked satisfactorily on even the warmest days proved that the radiator was more efficient as a heat dissipator when operating as a steam condenser. It must be remembered that the same amount of heat must be taken care of by either system.

The inlet and outlet jacket-water temperatures were measured with ordinary thermometers placed in the jacket inlet and outlet pipes. The exhaust-valve-seat temperature and the exhaust temperature were measured by means of thermocouples of iron-constantan connected with a pyrometer (millivoltmeter). The range of temperatures covered with these thermocouples came on the almost straight-line part of the curve, and there was little difficulty in obtaining the true temperature after calibrating the thermocouples in melted lead, zinc, and salt. The exhaust-valve-seat couple was insulated in concentric tubing of glass and porcelain. The junction was left exposed and forced close to the metal at the bottom of the hole which was drilled within $^1/_{16}$ to $^1/_{32}$ in. from the surface of the valve seat. The couple was held firmly in place by using "smooth-on" to fasten the glass tubing in place on the outside of the hole. The wires were well insulated throughout the entire circuit, so the temperature readings can be considered fairly accurate even though the junction was not actually imbedded in the metal of the valve seat. The couple placed in the exhaust pipe was enclosed in quartz tubing having the end closed. The leads to the junction in the tube were separated by mica and asbestos, which effectively insulated them.

The complete testing unit, that is, the engine with its brake and the instrument board, was arranged in such a way that the testing could all be done by one man. The thermometers placed on the engine could all be conveniently read from a bench placed in front of the instrument desk. The tachometer was of the hand type, set in a cradle which held it level. It was driven by a piece of rubber tubing which fitted tightly over the tachometer shaft and a short pin driven into the center of the brake drum; this provided a positive drive. The inlet pressure was recorded by a mercury column and the exhaust pressure by a differential water gage. The Chevrolet oil gage and ammeter were also mounted on the instrument board.

In order to get the revolutions and time during a run, a device[5] was made to automatically operate the stop watch and Veeder counter with magnets. These were controlled by the beam of the scale upon which the amount of fuel consumed was weighed.

This device functioned perfectly during all the runs and checked very accurately with the tachometer used, and with still a third, very accurate, hand tachometer. It also eliminated the human-element factor. The reason that the average r.p.m.

[5] Described in detail in the unabridged thesis.

as determined by the counter did not check exactly with the tachometer r.p.m. every time, was not due to an error in the counter and stop-watch device, but to the difficulty of holding the brake load at the constant r.p.m. desired.

Method of Testing

Runs were made each day with both steam cooling and water cooling.[6] The friction brake operated satisfactorily at speeds of 1000 r.p.m. and up, but could not hold the load steady at speeds

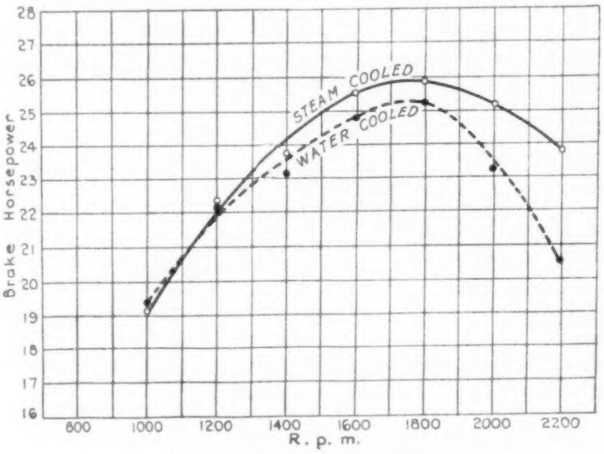

Fig. 3 Brake-Horsepower Curves

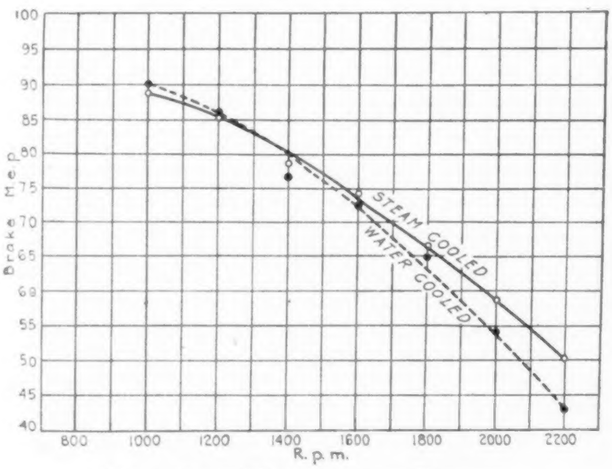

Fig. 4 Brake Mean Effective Pressure

lower than this. The runs, therefore, were started at 1000 r.p.m. and at increases of 200 revolutions up to 2200 r.p.m. It has already been mentioned that on the hot days the water could not be cooled sufficiently when operating with water cooling at speeds of 2200 r.p.m. (and sometimes 2000) without an overflow from the radiator. The temperature of the outlet water was considerably above 212 deg. fahr. when steam was generated too fast to allow the small overflow tube in the radiator to take care of the discharge required to keep the pressure at 14.7 lb. In making comparisons, however, by taking averages of all the runs, those steam-cooling results of each day, obtained at speeds where no equivalent water-cooling results could be obtained, were disregarded.

On some days the water-cooling runs were all made first as indicated on the log sheets. On other days all the steam-cooled runs were made first. Still other runs were made by operating first steam cooling at a certain speed, followed by a water-cooled run at the same speed. In this last method of testing, sufficient time was given to the motor to allow it to reach its normal operation and performance at that speed. An average of all the results obtained by this variation in testing should surely be a fair means of making comparisons.

Although the set-up was arranged for one-man testing, two men were really needed, because of the constant attention required by the brake. Enough fuel was used to allow each run to take at least three minutes, as specified in the S.A.E. test code.

After the load had been held sufficiently long to allow the engine to reach its normal performance at that speed, and to allow the temperature to reach a constant value, the test was started by closing the valve from the main fuel tank, and opening

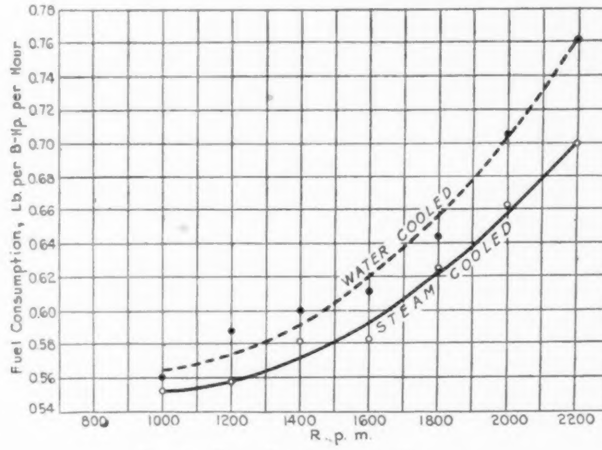

Fig. 5 Fuel-Consumption Curves

the valve leading to the fuel glass on the scales. As soon as the scale beam fell with the resultant starting of the stop watch and counter, the weight, equivalent to the desired amount of fuel, was lifted from the right-hand scale pan. Then the different instruments were read by the observer while the second man held the brake load steady at the desired speed. The brake load was read when the tachometer actually read the r.p.m. of the brake and when the brake operator's hand was lifted from the brake screw on the brake arm. The test ended with the stopping of the watch and the counter.

The fan supplying the cooling air to the radiator was run at maximum speed, giving maximum air flow, when operating the engine water-cooled. When operating with steam cooling, the speed and therefore air flow of the fan was cut down in order to allow the outlet water to reach 212 deg. fahr. Real steam cooling was then obtained not only by regulating the amount of circulating water but by varying the amount of cooling air.

Results

Before making any final comparisons, the readings of each day were corrected. The actual temperatures of the valve seat and exhaust were taken from the calibration curve of the thermocouples. The actual brake horsepower was reduced to the probable horsepower at 68 deg. fahr. and 760 mm. Hg. This was done to correct for the change in volumetric efficiency at different temperatures and pressures.[7] This naturally makes the results more comparable and leads to smoother curves when taking averages.

It has already been mentioned several times that the steam

[6] The unabridged thesis contains the original and corrected data.

[7] The formula used for this correction is given on page 338 of "Testing of High-Speed Engines," by A. W. Judge.

cooling system worked successfully at all engine speeds up to 2000 r.p.m. even on the warmest days; on one or two occasions only did it boil over at 2200 r.p.m. It was difficult, however, to get satisfactory runs above 1800 r.p.m. with the water-cooled system on hot days, even with maximum cooling air through the radiator. This proves conclusively in itself that the radiator is more efficient when used as a condenser than as a radiator, and the advantage is with steam cooling. It will be best, therefore, to study the effects on engine performance at this point to see whether the steam cooling produces any detrimental effects in the performance.

The first comparison will be between horsepowers. The accompanying curves, Fig. 3, show that water cooling produces a slightly higher brake horsepower at low speeds, but that above 1200 the horsepower with steam cooling exceeds the other. The steam-cooling curve rises at a greater angle, but the top of the curve is flatter than that of the water-cooled curve. The maximum horsepowers, however, are both obtained at an engine speed of about 1760 r.p.m., and therefore the results at 2000 and 2200 r.p.m. might be disregarded. There is really no explanation we can

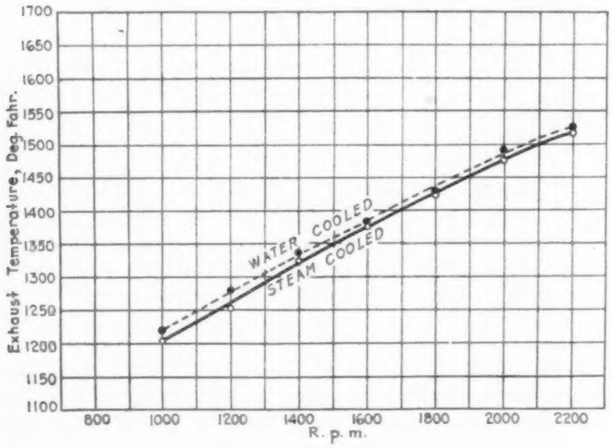

FIG. 6 EXHAUST-TEMPERATURE CURVES

make of these results at this point except that it is quite evident that the increase in power due to the lower piston friction when operating steam cooling, is greater than the loss of power, if any, due to the possible decrease in volumetric efficiency. The author uses the expression "possible decrease in volumetric efficiency" because Alex. Taub[8] found in his experiments that there is no material effect on the volumetric efficiency caused by the higher average temperature. If we look more closely at these curves, we shall notice that there really is only a slight increase in brake horsepower, but that the maximum horsepower is carried over a larger number of engine speeds with steam cooling than with water cooling. The small difference of 3 hp. at 2200 r.p.m. can easily be attributed to the dropping off in power with water cooling because of insufficient air being provided to the radiator for proper cooling.

The brake mean-effective-pressure curves, Fig. 4, are more or less directly connected to the horsepower curves, as the factor which changes the horsepower, namely, the torque, also changes the mean effective pressure in the same way. We can see from the curves, however, that there is only a slight difference in the pressure at speeds up to 1700 r.p.m.; the difference at 1800 r.p.m. being only $2^1/_2$ lb. per sq. in.

The fuel-consumption curves, Fig. 5, are much more interesting. They show that with constant-temperature operation at 212 deg. fahr., the fuel consumption is lower than when water cooling is used. Also a better and more accurate curve can be drawn through the points obtained with steam cooling, which shows that there is less variation in the fuel consumption when changing from one speed to another. The temperature of the air to the carburetor is an important factor in the fuel economy of an engine, and allowance should really be made for the difference in this temperature when operating steam cooled and water cooled. However, at the higher speeds, or from 1600 r.p.m. up, the temperatures of the carburetor air were about equal for steam-cooled

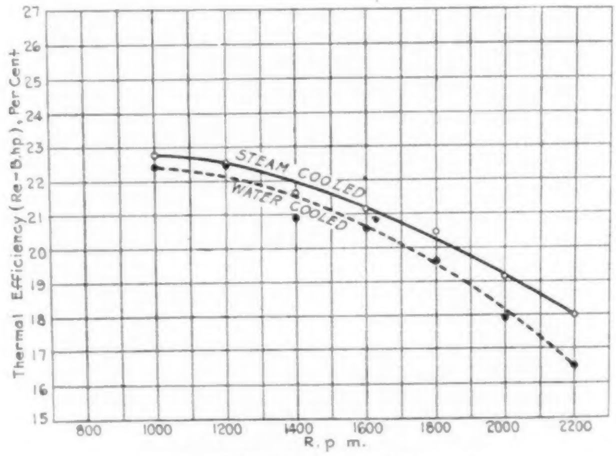

FIG. 7 THERMAL-EFFICIENCY CURVES

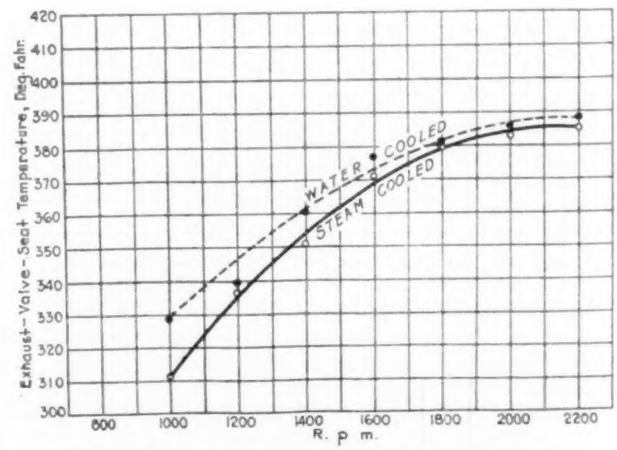

FIG. 8 EXHAUST-VALVE-SEAT-TEMPERATURE CURVES

and water-cooled runs, and yet there is a larger difference in the fuel consumption at these speeds. This result obviates the necessity of making any complicated correction for this difference in temperature, as it must be remembered that these tests were made for purposes of comparison only.

It is apparent from these curves and the horsepower curves that a slight increase in horsepower was obtained with steam-cooled over water-cooled runs when a smaller amount of fuel was consumed. This result is further checked by the fact that the exhaust gases were cooler with steam cooling than with water cooling. See Fig. 6. It can be readily understood that when there is a smaller amount of fuel in the cylinder, the exhaust gases will not reach as high a temperature as when a greater amount of fuel is used. The fact that a greater horsepower resulted also indicated that a larger amount of the heat of the fuel was absorbed in power and less lost to the exhaust. This means that the constant temperature of 212 deg. fahr. around

[8] Development Engineer, General Motors Corp.

each cylinder favored and helped combustion. This is a very desirable feature of steam cooling as the power output from each cylinder should be the same. In the case of water cooling, it is probable that the cylinder which is located near the intake of the jacket water does not produce as much power as the warmer cylinder near the outlet of the jacket water. It must necessarily be a fact that if the temperature around the cylinder affects the power of that cylinder, the power in each of the cylinders of a water-cooled motor must be different. In the case of the steam-cooled system, the temperature of the water is maintained at 212 deg. fahr. Each cylinder supposedly gives off the same quantity of heat and generates an equal amount of steam. The steam bubbles immediately rise and flow out of the jacket near the cylinder head or valve passages, and at a high velocity. The bubbles of steam from the cylinder farthest away from the outlet of the water jacket can only be superheated slightly as they pass the other cylinders, and it is only barely possible that the cylinder nearest the outlet can run a bit warmer than the others.

It is only natural with an increase in horsepower and a decrease in fuel consumption that the thermal efficiency of the engine is increased with steam cooling. The reader must consider the fact that the curves of Fig. 7 are drawn on a fairly large scale and that the difference in values on the curves is really quite small. For instance, the largest increase of thermal efficiency of steam-cooled operation over water-cooled operation is only $1^1/_2$ per cent at 2200 r.p.m. One who is familiar with the curves as drawn on the S.A.E. standard curve sheet might say that the curves shown here have excessive slopes, but a second glance at the range of ordinates will show the reason for this. The results as found in our tests all seem in favor of steam cooling, but when the curves are studied more closely, the differences are not as great as they appear from the distance between the curves. It can be said, however, that even if the performance of the motor with steam cooling is not greatly increased, but at least is equal to the performance with water cooling, its many other advantages overweigh the advantages, if any, of water cooling.

The exhaust-valve-seat-temperature curves, Fig. 8, at first glance seem unreasonable and incorrect. With a higher operating temperature of cooling medium, it is hard to believe that the valve seat would run cooler. When we observe that the exhaust gases were cooler with steam cooling than with water cooling, it might appear, as explained before, that the temperature in the combustion chamber was not as high as before. However, with an increase in mean effective pressure when operating steam cooling, the temperature in the combustion chamber must necessarily go up. The solution then lies in the fact that with steam cooling the heat is carried away faster than with water cooling. We must realize here that we are measuring the temperature of the metal as close as possible to the inner surface of the valve seat, but not the temperature of the combustion chamber.

When we consider the fact that steam bubbles are generated and that these flow out from the jacket at an extremely high velocity, they can carry off the same amount of heat from the engine much faster than water circulated by a pump. The steam bubbles naturally rise when formed, and in the case of the Chevrolet engine they flow through the cooling passages around the valves. With the high velocity of steam there is a better chance to carry away the heat in the valve seat much faster than with water cooling, and the temperature gradient through the metal is probably much steeper in slope with evaporative cooling.

There is always the great possibility that the water will become stagnant in some parts of the water jacket where there are restrictions and larger areas close together, and with water cooling the temperature of the water may rise considerably above boiling temperature even without actual boiling taking place. This would be caused by a rise in pressure in the system due to the restricted travel of any steam bubbles trying to get to the radiator through a pipe well filled with water. When the radiator is operated as a condenser, there is no pressure on the outlet pipe and the steam and water can pass freely to the condenser space. The water falls down to the bottom and the steam is condensed on its way to the bottom through the tubes of the condenser. Thus there is less chance of local stagnation occurring with the steam cooling system than with the water cooling system, and this in itself would account for any large difference in valve-seat temperature of the two systems.

Conclusions

Everything mentioned so far points to a great advantage of steam cooling over water cooling. There is one undesirable feature of steam cooling which it might be possible to eliminate but which exists to a certain extent in practically all of the steam-cooled systems so far designed. When the engine is stopped quickly after a hard run, the water in the jacket is at 212 deg. fahr. or at boiling temperature. There is still quite a bit of residual heat in the engine which must be dissipated, and naturally more steam is formed until the engine is at the same temperature as the water. This steam passes into the condenser, but no cooling air is provided, and the condenser quickly fills with steam which has to pass out through the overflow. If the engine is very warm, a pressure might be created for a short time and considerable steam may blow out with an accompanying loss of water. This can easily be prevented, however, by simply idling the engine for a few minutes after bringing the car to a stop. It takes very little cooling air to condense the steam formed by the residual heat of the engine. In winter, blowing off of steam and with it any alcohol in the system can be entirely prevented by idling the motor for a few minutes after stopping.

A reconsideration of all the results shows that with steam cooling there is slightly better or equal performance with quite a saving of fuel. Probably the most important fact after having conceded that the steam cooling system is the more efficient system in dissipating the heat of the engine which goes to the water jacket, is that the crankcase dilution is decreased to an almost negligible amount.

It can be seen too that quick warming up allows the pistons and rings to expand quickly, which will prevent the pumping of oil into the combustion chamber. This probably accounts for the fact that less carbon has accumulated in motors operating with steam cooling, as well as for the fact that there is less condensation of the gasoline with accompanying incomplete combustion.

The fact that the exhaust valve was cooler with steam cooling excludes all fears that temperatures might be reached in the engine which would affect the metal. The fact also that alcohol will not be lost during the winter is a point which should gain great favor with the public. The slight increase of horsepower will not be a great boon to the system, but the fact that heavy grades on hot days can be climbed without any "steaming" from the radiator will excite the interest of the summer tourist who carries heavy loads. A saving of gasoline will be of greater interest than the fact that piston friction is reduced. The decrease of crankcase dilution might attract many people, and the use of steam radiators in place of exhaust heaters will be considered only as an added luxury, but the fact that a smaller pump is required will hardly be noticed by the public.

There seems to be no doubt that steam cooling or constant-temperature running of the engine is more desirable than the present-day water cooling system. Some day a motor will be designed to obtain the largest number of the advantages offered by the constant-temperature engine. The change will be in the water jacket and the radiator, with the use of a much smaller pump; the appearance of the car will remain unaltered.

Real-Estate Aspects of Plant Location

When Manufacturing Seeks a New Site, the Industrial Realtor Must Have a Knowledge of Engineering to Do His Best Work for the Buyer and for the Community

By LLOYD W. MAXWELL,[1] NEW YORK, N. Y.

PLANT location is one of the important subjects coming within the realm of the realtor, the industrial engineer, the manufacturer, the investor, and the owner of available industrial property. Even city governments, chambers of commerce, boards of trade, merchants' and manufacturers' associations, industrial bureaus or commissions, and public-service corporations consider it one of their functions to keep informed on the subject of plant location and to formulate programs to attract industrial plants.

The real-estate aspect of the subject necessarily calls into the picture the industrial realtor. It is not the author's purpose to hold a brief for the broker. Usually the latter is able to speak for himself. Experience in plant-location work, however, and recent association with one of the leading industrial brokers operating in New York and New Jersey has given the author the faculty to consider the problem from the realtor's point of view.

The industrial broker works independently. His vocation is the buying, selling, or leasing of factory property as agent for a principal. He may represent either the buyer or the seller. However that may be, he works on a commission basis, he receives no remuneration unless and until a deal is closed, and he has to face relentless competition. It is not unusual for him to spend months or years on a prospect, advancing his own expense money, before consummating a sale.

Engineering Knowledge Required

The competitors of the industrial broker consist of other brokers, industrial engineers, lawyers, manufacturers, and property owners. Frequently a manufacturer seeking a location for a plant will employ an engineer to choose a suitable site. In this case it is assumed that consideration will be given to the sources of raw materials, transportation facilities, labor and power supplies, markets, regulatory legislation, and other pertinent factors. If land that meets the requirements is readily available, a broker may have no chance to enter into the deal. As a rule, however, the engineer will find it advisable to consult a reputable broker in order to obtain alternative proposals and to learn the values of real estate. Attorneys often try to handle real-estate transactions for their clients on a fee or commission basis, and owners sometimes endeavor to sell their property direct with the idea of avoiding payment of a brokerage commission.

Such competition serves as an inducement to the broker to provide himself with the best possible mental equipment and to supplement that with an efficient staff. He finds it advantageous to be himself an engineer, and to have legal, research, and sales talent among his office force. In addition to this he must establish a record for fair dealing, and must be able to refer to a number of influential and satisfied clients.

Plant location has become a science. From the manufacturer's point of view it is very important that he be located at the most strategic spot and at the right price. While the industrial engineer can go a long way toward meeting the scientific needs of plant location, the broker, in order to survive and to prosper, has had to go beyond the scope of the engineer. By adding the engineer's functions to his own knowledge of salesmanship, real-estate values, property surveys, and price arguments, he has become the all-important individual in factory-location projects.

When an Engineer Is Called in

Even if there is an engineer in the deal, he usually is there for a purpose entirely different from that of the realtor. As a rule the engineer enters into the negotiation with the knowledge of or at the invitation of the prospective buyer. In some instances his instructions are for the choice of a site, but more often his function is to design a building. If the latter is his task, his desire is to get the contract, from which his remuneration will result.

The industrial realtor customarily is the agent of the seller of a property. Possibly he represents both seller and buyer, but he looks to the seller for his pay. As a part of his equipment to make him useful to the seller, he is possessed of a mass of valuable information which he has devoted years to collecting and which the seller is willing to pay for provided a sale is completed. The chances are that the broker knows intimately every piece of available property for miles around. In like manner he knows the price at which each piece is held, as well as the price that it is actually worth, and the rock-bottom price that the owner will accept. Furthermore he no doubt knows the price at which every sale in the neighborhood has been closed for years past. All this enables him to advise his client on values, so that the asking figure will not be set so high as to frighten away all prospective buyers.

It has seemed necessary, at the expense of considerable space, to lay this foundation for an understanding of the real-estate aspects of plant location. The broker is the central part of the picture. Being familiar with all of the available industrial property and deriving his sole income from commissions paid by sellers, his one guiding motive is to find buyers. When he discovers a purchaser and closes a deal, he locates a factory.

Data to Be Supplied

When the broker, armed with the knowledge and high motives attributed to him, approaches a prospective buyer, he is not limited in the kind or number of propositions which he may submit. It can make no tremendous difference to him which client's property he sells. The point with him is to make a sale, to earn a commission, to locate a plant, to build up a community, and to develop a clientele. A prime consideration with him is to cultivate good will, so that he may represent his clients again. His reputation as a professional man depends upon the character of his accomplishments. In collecting data concerning all available factory sites, therefore, in order to try his hand at locating new plants thereon, it is essential that he make his knowledge broad and comprehensive in relation to each site. He should be, and usually is, able to supply data touching every phase of the factory-location problem. It is not to his interest to locate a plant in the wrong place. Such a blunder would curtail his future business. Nor is there any excuse for him to make a blunder. It is always possible for him to submit a property which is in a logical location or to refer the inquiry to a cooperating broker in another section of the country.

[1] Assistant Chief Investigator, National Industrial Conference Board.

Address at a meeting of the Metropolitan Section of the A.S.M.E., sponsored by the Management Division, New York, April 13, 1928.

When an industrial engineer is employed by a manufacturer to choose the strategic location for a specific industry, he searches for a place which is logical from the point of view of labor conditions, transportation facilities, power, natural resources, markets, tax laws, and other regulatory legislation, costs of living, housing for employees, existing industrial development, and a score or more of other considerations. Everything possible is done to locate the plant at the point where costs can be kept at a minimum compared with the service rendered. Probably the engineer in the case goes to the real-estate broker for assistance. A friend of the author's, who happens to be an industrial engineer, during a trip to Scotland last summer, was called to Glasgow by a firm desiring to locate a plant in New York harbor. After talking with the principal and seeing that he was in no way ready to contract for the design of a building, the engineer told him that he was not ready for engineering advice, but that what he needed was the address of a reliable New York realtor.

What Is Best for the Community

The efficient realtor has no occasion to call in the engineer. Many prospective purchasers go directly to the realtor, explain their requirements, and solicit advice.

Frequently the broker learns that the prospective manufacturer does not know his own mind or his needs. This gives the realtor a chance to do constructive work for both buyer and seller, as well as for the community. From many possible sites, all of which he has analyzed carefully, he may select the most suitable one, submit it to the prospect, and with unimpeachable argument advise him to accept it.

There are several points in connection with plant location wherein the attitude of the real-estate man might differ from that of the engineer, the attorney, or the seller of land. In the first place, the realtor, if he knows his business, will not put an industry into a community where it will be a nuisance. His program is to build up the community for the purpose of increasing real-estate values. Not only would his reputation be endangered by endorsing a nuisance, but adjacent property would be damaged and future sales thereby would be more difficult and less remunerative.

In the second place, the industrial realtor does not want to locate a plant on land which is too high priced. The original outlay for the site may have an important bearing upon the ability of the organization to carry the costs of operation. Enough cases have been seen where a building has been erected—a monument to someone's blunder—in an area where land cost too much, where labor was not available, or where transportation was too costly; and real-estate interests should do all in their power to prevent such errors. To locate an industry in a city, for instance, where all of the materials for manufacture must be brought in by rail from a distance and then lightered across intervening water, would be an illustration of costly production which the industrial real-estate fraternity would not approve.

Thirdly, the real-estate man is in better position than any one else to know from experience what the railroad company will do about putting in additional sidings or new sidings, or what can and should be done to improve waterfronts or to obtain riparian rights.

Fourthly, the real-estate man is not interested in receiving a retaining fee for traveling over the country to seek the logical location for a rayon mill or any other type of factory. The realtor lives and operates in a community. His program is to develop that locality by bringing in new plants. He is well aware that to make property salable in his neighborhood the zoning ordinances must be equitable, the legislation of the state must be fair to industry and to labor, the transportation and power facilities must be adequate, and in other respects the section must be attractive to manufacturers.

Analyzing the Industrial Situation

This logically puts the realtor in the role of community builder, civic leader, and student of economic and industrial trends. If he has chosen New York City as his base of operations, he will soon become familiar with the industrial status of this state. It is well known that the concentration of one type of industry in a locality tends to attract other plants of the same kind. This is an important consideration in the sale of real estate. The prospective automobile manufacturer might wish to go to Michigan, yet the real-estate man may eventually be able to bring him to New York, because in 1923 the state of New York ranked third among all the states in the manufacture of motor vehicles. Only Michigan and Ohio were ahead. Other states which often are recognized as the homes of good automobiles—such states as Indiana, Missouri, New Jersey, and Wisconsin—rank below New York in the value of motor vehicles produced.

This point brings up the desirability of analyzing briefly the industrial situation in New York. Statistics from the Bureau of the Census show that New York is the leading industrial state of the Union. In value of product, number of wage earners, and number of establishments it is ahead of every other state. For the purposes of the present discussion, these points are germane in that they indicate the types of industry which may be attracted. Let us extend the analysis, therefore, to specific industries.

Knowledge of Each Industry's Needs

The manufacture of clothing is the greatest industry in the state, and the greatest state industry in any state of the Union. In 1923 the value of this state's clothing product was $1,636,529,625. Only two other states have industries in the billion-dollar class, one being the iron and steel industry in Pennsylvania and the other the automobile industry in Michigan. New York has so little competition in the clothing industry as to be almost negligible, while it stands fifth in the iron and steel industries and third in the automobile industry. This ought to indicate to the realtor that he has strong arguments for presentation to prospective producers of these lines of goods.

If the twenty-five leading industries in New York be selected on the basis of the value of their products, and compared with the records of the seven other states taking highest rank in those same industries, it will be found that New York State takes first rank sixteen times out of the twenty-five and that no other state ranks first more than three times. From this study it may be determined that the states producing sufficient values in manufactured products to be classed as industrial competitors of New York are Pennsylvania, Ohio, Illinois, New Jersey, Massachusetts, and Michigan.

This is splendid foundation material for the industrial man whose business is to locate new plants, whether this man be a realtor, an engineer, or the bearer of some other name. Knowing which states may offer the keenest competition and which industries he may expect to bring most easily and logically to his community, he studies those states and those industries.

Migration of Business a Factor

It stands to reason that an industry which is growing in the state, and is in a healthful condition, can be increased by the addition of new plants. It is an interesting sidelight on the New York situation that of the twenty-five leading industries of the state, as determined by the value of their products, all of them grew, and in most cases enormously, between 1914 and 1923. On the basis of number of establishments within the

state, however, several of those twenty-five various industries declined. The growth of industry when measured by value of product, coupled with its decline when measured by number of establishments, could be attributed to various causes. It might be due to the spur of competition, to labor-saving machinery, or to the combining of enterprises to afford the advantages of economy of production. Whatever the cause, the industrial realtor or engineer must delve to the bottom of it, for such things have a direct bearing upon his ability to locate new plants.

At the present time the iron industry and the shoe industry are moving westward. The cotton textile industry, on the other hand, is moving to the South. These are national movements, each with an economic reason back of it, and the man dealing with industrial property would waste his time and effort were he to oppose them. His game is to discover which industries are coming, or which logically may come, to his locality, and then to concentrate on them.

Influence of State Laws

It is essential from the real-estate point of view for the operator to be cognizant of the labor laws and other regulatory legislation of his state as well as of competing states. Too much legislation discourages plant location. There is little hope for the real-estate man, or the engineer, or the chamber of commerce secretary in attempting to locate new plants in a state or city which legislates so severely as to convince manufacturers that they can do better in some other jurisdiction. Recently the National Industrial Conference Board made an analysis of regulatory legislation in New York to determine how this state stands in relation to other states. No doubt every industrial realtor will be thinking along the same line, for his success, and the success of his movement, depends to a great extent upon whether conditions are right in the state for new industrial plants.

Not long ago Charles P. Wood, industrial engineer of Lockwood, Greene & Co., read a paper in Massachusetts on "The Influence of State Laws on the Amount and Cost of Industrial Production." He maintains that there are many ways in which state laws may influence, either favorably or adversely, the amount and cost of industrial production. This is another way of saying that plant location may be made easy, or on the other hand, practically impossible, by state legislation. States which build up great industrial communities, and then tighten their restrictions unduly, may find their development cut off. Real-estate men dealing in sites for new plants will agree with these views of Mr. Wood. Conservation laws, the policy toward transportation or the maintenance of highways, labor laws, wage laws, laws limiting hours of work (generally relating to women), tax laws, and workmen's compensation laws all have their influence upon the manufacturer considering a plant location. It is the duty and the pleasure of the operator in industrial real estate to lend his influence to fair legislation on these and kindred subjects and to work for legislation which is equitable in comparison with that of other states. Even if it could be done, it would not be good business from the realtor's point of view to locate a new plant under conditions sure to produce a dissatisfied client.

Realtor's Work Must Be Inclusive

In conclusion it may be said that the real-estate aspects of plant location are the material aspects which cause new sites to be chosen or which influence sales of industrial property. Whatever is good economics, or good engineering, or good social science in plant location, is good from the real-estate point of view. The last man to figure in the transfer of property for the establishment of a new plant is the realtor. His work is influenced so tremendously by the engineering and economic phases of the question that he has found it to be good policy to incorporate these factors in his own working equipment. Like the major political party, in taking over the most popular planks of a weaker party's platform, so the industrial real-estate man, having the jump on all competing professions in the matter of handling real estate, has taken everything good from all of them.

The real-estate aspects of plant location, therefore, are not especially different from other aspects except that they are all-inclusive. They are the community aspects—the aspects which make towns and cities grow because they transfer industrial property to hands which can make better use of it. To find buyers for industrial property means the finding of persons who will establish new plants. This is the function of the industrial realtor, and the methods that he uses consist of an accumulation of the approved methods which have been used previously by engineers or other successful operators.

English Shop Practice

IN SHOP buildings, the tendency is toward single-story construction with a saw-tooth roof. I was in several multistoried structures not very different from corresponding buildings in the United States. The English saw-tooth roof differs from the American in that both rafters are set at the same angle to the horizontal, about 30 deg. The north side is glazed, the glass being painted to shut out direct rays of the sun. In this connection it should be remembered that England is farther north and that direct sunlight is not nearly so devastating as it is in America.

On a clear day shops of this type are very well lighted indeed, but I got the impression that illuminating engineers in England have not been so successful in introducing high intensities of artificial light as have been their American colleagues. They may have been hampered by the many different voltages and cycles provided by the English public utilities.

Brick work in the side walls of the single-story building is run higher than is customary in America, and but little clear glass is used. Those inside are apparently not expected to do any looking out, which is a great pity because the English countryside surrounding many of the newer plants is more than charming. On the other hand it must be remembered that the workers have much more daylight in the summer after shop hours than we have. In June the sun does not set until 10 o'clock, daylight saving time, and then there is still light in the sky an hour and a half later. They pay for it in winter. Inside the English shops the visitor familiar with the latest American practice is struck at once by the number of belts in use. Motor-driven machines are almost non-existent, except for certain specialized American tools. English machine tool builders, apparently, have given but little attention to built-in motor drives. I was told, however, that they are beginning to do so now. The millwright in an English shop is consequently an important personage. I saw well-arranged group drives, and, in one shop, a complete installation of hangers fitted with anti-friction bearings.

Single-purpose machines are apparently less numerous than in American shops, a condition that may be explained by the small size of the lots going through. In the one shop visited where really large quantities of small parts were in process, plenty of machinery designed and built in the plant was in use and more was under construction. Most of the jigs I saw were of the single-unit type. Indexing and two-unit jigs are little used, and the explanation given was that the lots are too small to justify the high cost of the more complicated fixtures. (K. H. Condit in *American Machinist* for July 26, 1928, pp. 151–152.)

Modern Quantum Theories

A Historical Survey of the Development of the Physics of Radiation From the Electromagnetic Theory of Maxwell to the Quantum-of-Action Theory of Planck, Bohr, and Einstein

First of a Series of Articles on Modern Physical Theories for Engineers

By LEON CAMMEN,[1] NEW YORK, N. Y.

THE IDEA that many processes involving material phenomena occur by means of flow is a very old one. The flow of water and other liquids was one of the forms of motion of matter easiest to observe and strongly impressed the minds of the early physicists. As more became known about wind it was easy to assume that the movement of air takes place substantially in the same manner as that of water, the result being the evolution of the idea of "fluids" which included both liquids and gases. Later on this was expanded to a number of other phenomena and thus appeared the conceptions of a "life fluid," of phlogiston, etc. Heat was a fluid that flowed from a higher to a lower level of temperature. When more became known of electricity, the same idea of fluid was applied to explain what even today we call the flow of current, both words of this term being throwbacks to the original conception of electricity as a kind of fluid obeying in ways of its own the general laws of fluid flow. Under this conception voltage acquired the characteristics of pressure approximately in the same way as pump pressure sending water along a conduit, while the electricity itself was described as current, or, less elegantly, as "juice."

There is one underlying conception in all of this, and that is, continuity of flow. When water is flowing we assume that this flow consists of an aggregation of an enormous number of molecules, each consisting of hydrogen and oxygen in certain proportions, and in the flow the molecules are substantially equidistantly spaced. The flowing liquid has therefore only molecular subdivisions within it. If we compare the flow of water to, let us say, the movement of small shot down an inclined plane, we shall immediately notice a fundamental difference between the two. Every little ball of shot, assuming it to be made, say, of pure lead, consists of an aggregation of molecules of lead fashioned by external forces into the form of a small sphere. In the moving stream, each one of these little spheres retains substantially unaffected its molecular aggregation and structure. But the spacing of the spheres themselves depends on a number of factors independent of their internal aggregation, as, for example, the angle of incline of the plane, the number of balls of shot moving, the roughness or smoothness of the plane and the balls, the degree of their crowding, etc. In the case of flow of water, on the contrary, at first glance we see only the molecular aggregation and there appears to be nothing similar to the interrelations between the individual spheres of shot. That such appears to be the case at first glance is said advisedly because it is probably not entirely correct even in the case of water.

Early Theories of Radiation

It was natural, in dealing with liquids, gases, and such quasi fluids as heat and electric current, to assume a flow characterized by the principle of continuity. In fact, several theories, in particular Maxwell's electromagnetic theory of light, made it particularly imperative to assume such a flow. It was the study of heat radiation, however, that brought about the first doubts that the principle of continuity was an inherent characteristic of flow phenomena in nature.

Kirchhoff was the first to formulate a theory of radiation which was sufficient to cover the main facts. He was the first to place the main emphasis in radiation phenomena not on the amount of heat emitted by the body but on what it absorbs. If the body absorbs the entire heat radiation falling upon it it is called "black," this term meaning here not the opposite of white but the opposite of "perfectly reflecting." According to Kirchhoff, the emissive power of a black body depends solely on its temperature. Later, Stefan and Boltzmann found that the emissive power of a body is proportional to the fourth power of the absolute temperature of the body. Hence, the ratio between the emissive power of a black body and the fourth power of its absolute temperature is a constant (Stefan's law).

Next came the question of the character as distinguished from the amount of the radiation from a warm body. Waves of radiated heat were found to have different wave lengths, the aggregation of which constitutes a spectrum of emission. Not all parts of the spectrum act equally in the radiation from a warm body and the share of each varies with the temperature. The problem of spectral distribution of the energy of radiation when investigated has shown that if the intervals of temperature of the radiating body are chosen to be very small, within each interval a definite wave length can be found for which the specific emissive power is greatest.

Wien then found that the product of this wave length and the absolute temperature of the radiating body is a constant (Wien's constant). From this another law called the displacement law was derived which states that the wave length is displaced with increase in temperature in the direction from larger to smaller lengths, or, within the visible spectrum, in the direction from red to violet, i.e., the wave length decreases with the increase in temperature of the radiating body. The trouble is, however, that neither of these two laws seemed to possess general validity and held good only for a limited range of application.

To understand what happened next we have to go back to Maxwell's theory on electricity and light. According to Maxwell, in a traveling train of light waves the electric field and the magnetic field stimulate one another alternately and reciprocally and for this reason the wave train travels. Maxwell had not conceived of particles of electricity and as Karl K. Darrow[2] stated, his conception of electric fluid was indeed so highly formal that it gave point to the celebrated jest about the man who read the whole of Maxwell's "Electricity and Magnetism" and understood it all except that he was never able to find out what an electrified body was. H. A. Lorentz incorporated the electron into Maxwell's theory. He assumed an electron to be a tiny sphere of negative electricity held in a position of equilibrium by certain restoring forces. This introduced the conception of "bound" electrons. Displaced from its position of equilibrium by some transitory impulse and then left to itself, the bound

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This article does not represent results of original research but merely a popularization of material already published. For further information readers are referred to the references given throughout the article. Free use was made of these books in the preparation of this article. A second article covering more recent theories will appear shortly.

[2] Karl K. Darrow, "Introduction to Contemporary Physics," D. Van Nostrand Co., New York, 1926.

electron would execute damped oscillations, emitting radiation at a rate determined by its oscillations.

Planck's Theory of the Quantum

In 1902 Max Planck published the result of his investigation on the character of the radiation of heat inside a completely enclosed or nearly enclosed cavity whose walls were maintained at an even temperature. According to Stefan's and Wien's laws the character of the radiation, meaning thereby the absolute intensities of the rays of all the various frequencies, should depend only on the temperature of the walls of the cavity and not on its material.

According to Lorentz's modification of Maxwell's theory the walls of the cavity are densely crowded with bound electrons, bound in all sorts of ways with all magnitudes of restoring forces, so that every natural frequency of oscillation over a wide range could be found among them. Even before Planck it was suspected that the character of radiation within a cavity was not completely explainable by the electromagnetic theory of radiation. Planck definitely showed that if the bound electrons in the walls of the cavity did really radiate as they oscillate in the fashion prescribed by the electromagnetic theory, then the character of radiation in the cavity would be totally different from what he had observed it to be.

On the other hand if the bound electrons do not radiate energy while they oscillate but accumulate it as Planck now suggested and finally discharge it in a single outburst when the energy attains some one of a certain series of values ($h\nu$, $2h\nu$, $3h\nu$, etc., where h stands for a constant factor and ν for the frequency of vibration of the electrons of the emitted radiation), then the character of the radiation will agree with that which he observed, provided a suitable value is chosen for the constant h. This value is not absolutely certain even yet, but is now given as 6.56×10^{-27}. To designate the apparent corpuscular nature of this discontinuous flow of energy in discrete particles as compared to the uninterrupted stream of energy assumed by the classical theories held up to that time, Planck spoke of radiation of heat by "quanta of action." The difference between the steady flow of water from a hose nozzle and the rapid succession of bullets from a machine gun serves as a graphic, although imperfect, analogy to the theories of energy radiation as held by Maxwell and his followers and Planck.

Planck's law of radiation correctly represents the distribution of the energy of radiation over all parts of the spectrum at all temperatures. It goes further than that, however, because it introduces a radically new conception of the flow of heat in at least this one instance of heat radiation, a conception in entire disagreement with what might be called the previous classical theory. Where Maxwell, Lorentz, Stefan, and Wien saw a continuous radiation, Planck put forward the claim, and for his particular case proved it, to the effect that before radiation could occur a certain amount which he called quantum of energy had to be accumulated. In other words, electrons might oscillate without radiating energy which would be impossible under the Maxwell theory. The great question was therefore whether the Planck concept of a quantum of energy applied only to the particular instance of heat radiation or whether it had a more universal application. The first to pronounce in favor of the latter was Albert Einstein, later made famous by his theory of relativity. That even Einstein was anything but sure of the conclusiveness of his truly magnificent expansion of the quantum theory is shown by the fact that he described it as heuristic, i.e., inciting discovery.

Planck limited his idea of quanta to energy emission only. As he saw it, an electron oscillated until it collected a certain amount of energy and then discharged that amount in one burst, like the small boy who has saved pennies for weeks only to spend them in one great splurge at the candy store. Einstein presented the idea that these fixed quanta of radiant energy retained their identity throughout their wanderings through space from the moment of emission to the moment of absorption. Going back to the distinction between the flow of water on one hand and of a number of shot on the other hand, the Maxwellian theory of the behavior of radiation was somewhat like the flow of water. Each electron in its vibration produced something like a tiny opening at the bottom of a tank through which water flowed in a constant stream, mixing with other streams. Under the Planck-Einstein theory the flow proceeded as if coming from a cloud, in which condensation may be assumed to occur in such a manner that drops of liquid are formed which retain their identity without mixing with other drops, from the moment they leave the cloud miles up in the air to the time they strike the ground.

The two conceptions are obviously not reconcilable between themselves and if Planck and Einstein are right, the Maxwell theory falls to the ground, and a foundation is provided for an entirely new idea of the whole system of the structure of matter. The only question is: Can it be proved that the quantumt heory is correct? This is of interest from two points of view. In the first place, the mechanisms of energy phenomena are becoming of importance to mechanical engineers and will be increasingly so as time goes on. Quantum mechanics lies at the base of investigation of all such phenomena and it behooves a mechanical engineer to know whether or not this fundamental theory has been established on a sufficiently sound basis to warrant his use of it. In the next place, the impression among non-physicists prevails that work in the domain of subatomics and with electrons and their vibration may be classed with the popular idea of the measurement of the distance to Mars by astronomers, according to which the astronomers guess one-quarter of the distance and then multiply their guess by four to obtain the whole distance. To an engineer, as to many laymen, it does not seem possible that a magnitude such as quantum $h = 6.56 \times 10^{-27}$ can be determined with the precision indicated, particularly when we consider that electrons cannot be seen, and when, if we take for granted Schrödinger's theory, they may not be of a corpuscular nature at all. The inquiry is not at all infrequent as to how much reliance can be placed in measurements involving bodies which may not exist as bodies at all. As a matter of fact—and one of the purposes of what follows is to show it—we are in approximately the same position in this matter as the electrical engineer who does not know for certain what electricity is, but who can measure with any degree of desired precision voltage, amperage, wattage, frequency, inductance, etc.

Application of Quantum Theory to Photoelectric Effect

The first case to which the quantum theory was applied outside of the phenomena of heat radiation was the photoelectric effect. Hertz was the first to find that metals emit, when illuminated, something which he later determined to be electrons, the emission differing with the kind of metal and being quite powerful with some of them, for example, sodium, potassium, and lithium. It was also found at a comparatively early date that the emission is effected by the light and varies under the action of various monochromatic illuminations. Einstein at a very early date predicted that the energy of emission of electrons under the influence of light would be covered by the equation

$$mv^2/2 = h\nu - p = Ve$$

Here the expression to the left of the first equality sign is the energy with which the electron leaves the surface, and does not differ from the conventional equation for kinetic energy. This

energy obviously is equal to the product of the charge e of the electron by the potential difference V against which it is just able to drive itself before being brought to rest, in the same way as the kinetic energy of a bullet shot upwards in a vacuum may be measured by the height to which it rises. What Einstein added, however, was that this energy is also equal to the frequency of vibration ν times Planck's constant less the amount of energy that the electron expends in breaking through or away from the boundary layer of the solid metal. At the time when Einstein made this prediction there was absolutely no experimental data to support it. It followed, however, that if Einstein's formula could be proved it would not only explain the character of the photoelectric radiation but would give powerful support to an extension of the Planck theory of quanta and raise it from a single effect dealing with heat radiation in an enclosed cavity to the position of claimant for the dignity of a universal law.

According to the above equation the kinetic energy with which monochromatic light ejects electrons from any metal is proportional to the frequency of the light vibration, p being so small as to be almost negligible in comparison with $h\nu$. Hence, violet light having only half the wave length of red light should throw out the electron with twice the energy imparted to it by the red light. The correctness of this equation was tested in the Ryerson Laboratory.[3] Cast cylinders of sodium, potassium, and lithium were placed in a vacuum in such a manner that a knife operated from outside by an electromagnet could cut fresh surfaces on the metal, whereupon the freshly cut surface could be exposed to a beam of monochromatic light from a spectrometer. The energy of the electrons ejected by it was measured by applying to the surface a positive potential just strong enough to prevent any of the discharged electrons from reaching a gauze cylinder and communicating an observable negative charge to the quadrant electrometer attached to this gauze cylinder. This is, of course, only the briefest outline of the device.

If Einstein's theory is right there should be a linear relation between the applied positive volts and the frequency of the light, and the slope of this line should be exactly equal to h/e. Since e is known, h can be obtained from the slope of the line. A most careful investigation has shown in the first place that the observed data lie remarkably close to a straight line and from the slope of this line h was found to be 6.26×10^{-27} erg sec. which is as close to the value obtained by Planck (6.56×10^{-27}) as can be expected from the accuracy with which the experiments can be made.

This appears to afford satisfactory experimental evidence that the Einstein equation for emission in the photoelectric effect is correct and in the second place that the Planck constant expressing the quantum of action is not confined to the case of heat radiation in an enclosed cavity alone but has a more universal application.

Karl K. Darrow[4] expresses this as follows: "Photoelectric emission occurs as if the energy in the light were concentrated in packets or units or corpuscles of amount $h\nu$ and one whole unit were delivered over to each electron." Millikan's and other experiments, such as the excitation of radiation by electrons stopped in their flight by collision with a metal, and excitation of the ray forming a single line spectrum by the collision of an electron against an atom, were all found to occur as if radiant energy of given frequency ν were concentrated into packets of energy amounting to $h\nu$ and each packet were created in a single process and absorbed in a single process. In all cases the most careful experimentation possible gave for h values approaching to the Planck constant of 6.56×10^{-27} (within limits of experimental error) which apparently established the Planck constant as having an actual physical significance and incidentally modified the entire conception of the method of transmission of energy from a continuous to a discontinuous process.

CONTRIBUTIONS BY NIELS BOHR

The next obvious step was to transfer this new conception to the field of interpretation of the structure of matter, and this step was taken in a remarkable way by a young Danish mathematician, Niels Bohr.

In the latter part of the nineteenth century there was an increasing realization of the facts (1) that an electric charge possesses the most distinctive property of matter, inertia; and (2) that all electric charges are built up out of electric units all alike in content of energy. Electricity and matter began to be accepted as different aspects of one and the same thing. It was only, however, the discovery of radium which actually ejects negative electrons at speeds which can be accurately measured and which vary from 0.3 up to 0.98 of the speed of light, which permitted the conclusion that within these limits the observed rate of variation of the mass of the negative electron with speed occurs exactly in accordance with the rate of variation of the mass computed on the assumption that this mass is all of electrical origin. This laid the experimental foundation for the claim that the origin of mass is electrical, and as R. A. Millikan[5] adds, "We know from methods which have nothing to do with the electromagnetic theory of the origin of mass, that the excessive minuteness predicted by that theory for both the negative and the positive constituents of atoms is in fact correct, though we have no evidence as to whether the foregoing ratio[6] is right."

It has been shown that the electronic or other constituents of atoms can occupy but an exceedingly small fraction of the space enclosed within the atomic system and that practically the whole of this space must be empty to permit an electron to move with the speed with which it is found to move. Bohr attempted to answer the question as to just how these movements take place. To start with, he considered the cases of hydrogen and normal helium, both of which contain one single electron revolving around the positive nucleus, the nucleus of helium being, however, four times as big as that of hydrogen. It has been previously found that hydrogen does not radiate energy at all unless it is ionized or has its negative electron knocked or lifted from its normal orbit to one of higher potential energy. When radiation does take place, it gives rise not to a continuous spectrum but to a line spectrum in which the frequencies or the positions of the characteristic lines as they appear in the spectrum are related to one another in accordance with a definite series controlled by successive integer numbers. Bohr assumed that the electron may rotate about a nucleus in a series of different orbits, each one of them controlled by the Newtonian law of orbits, these orbits being presumably circular. In Bohr's case, however, it was assumed that the negative electron maintains its orbit or persists in its so-called "stationary state" without radiating energy (just why it can do so Bohr did not explain).

Bohr's second assumption was that radiation takes place only when an electron jumps from one to another of these orbits. If A_2 presents the energy of the electron in one orbit and A_1 that in any other orbit, then it is clear from considerations of energy alone that when the electron passes from one orbit to the other the amount of energy radiated must be $A_2 - A_1$;

[3] R. A. Millikan, "The Electron," University of Chicago Press, 1924, p. 239, et. seq.

[4] "Introduction to Contemporary Physics," D. Van Nostrand Co., New York, 1926, p. 123.

[5] Ibid., p. 189.

[6] This refers to the ratio of the size of the positive electron to that of the negative which is said to be 2000/1.

further, since this radiated energy obviously must have some frequency ν, Bohr placed it proportional to ν, and wrote

$$h\nu = A_2 - A_1$$

h being the so-called Planck constant. It is to be emphasized that this assumption gives no physical picture of the way in which the radiation takes place, but merely states the energy relations which must be satisfied when it occurs.

Bohr's third assumption is that the various possible circular orbits are determined by assigning to each orbit a kinetic energy T, such that $T = \tau hn/2$, where τ is a whole number, n the orbital frequency, and h Planck's constant. This value of τ is assigned so as to make the series of frequencies agree with that actually observed. As Millikan[7] points out it is to be noticed that if circular electronic orbits exist at all, no one of these assumptions is arbitrary. Each of them is merely the statement of the existing experimental situation. They predict the sequence of frequencies in the hydrogen series, because they have been purposely made to do so, but they have not been made with any reference whatsoever to the exact numerical values of these frequencies. It should be also remembered, however, that Bohr nowhere explains just how it is possible for an electron to spin around the proton nucleus without radiating energy or why the electron stays only in certain orbits covered by the condition that τ in the above expression is a whole number. He just assumed that they do, and such experimental work as is available would tend to prove that Bohr is right.

Long before Bohr there was available an equation for the frequencies corresponding to the various lines in the hydrogen spectrum which involved a constant N (Balmer-Ritz equation, compare Millikan, p. 210). The Bohr theory makes it possible to express N in terms of e, which has been above referred to as the charge on the electron, and h, which is Planck's constant. Millikan redetermined e with an estimated accuracy of one part in a thousand and also determined h. With these two elements known, N has been determined from the Bohr equation and the value obtained happens to be within a quarter of one per cent of the observed value. As Millikan himself has done most valuable work in this connection, he points out that this agreement constitutes a most extraordinary justification of the Bohr theory on non-radiating electronic orbits.

The above is but one of the proofs of the correctness of the Bohr theory and a number of other proofs are available. In this way the existence of electronic orbits within atoms, similar to planetary orbits within a solar system, appears to be fairly well established, but as to the shapes of these orbits only little is known and about their orientation there is even less knowledge.

The Compton Effect

Planck's original conception that energy radiates in discontinuously accumulated amounts, called by him quanta of action, has been, as shown above, expanded by Einstein, who claims that these quanta of action preserve their identity from the time they are radiated to the time they are absorbed, and further investigation has confirmed the apparent correctness of the Einstein view. Taking now the quantum of light, we find that its energy is equal to $h\nu$ and its speed to c. Another formula developed by Einstein gives the relativity relation between energy and mass as energy$/c^2 = m$. Compton showed that as the momentum of the light quanta may be taken as mc where m is the mass, the substitution of the value of m from the relativity relation results in the expression $h\nu/c$ for the momentum. The question now arises as to what proof is there that each quantum is endowed with the inherent energy $h\nu$ and inherent momentum $h\nu/c$. The only apparent way to determine this would be to bring about a collision between the quantum of radiation and a free electron so that whatever momentum and whatever energy may exist will be transferred to the electron and must remain with it without being passed along to more massive objects where the momentum would be lost. The experimental difficulties in the way of such a test are obviously enormous and it is a fitting illustration of the high state of development of modern physics that not only has such an experiment actually been performed but accurate measurements have been made. This was done by Compton with the result noted below which is now known as the Compton effect.

If the Compton calculation is right, the light quantum, when colliding with a free electron, transfers some of its energy to the electron. Its energy however, is $h\nu$ in which h is Planck's constant. Therefore if the quantum arrives with the energy $h\nu_0$ it must recoil from the impact at some angle θ with a smaller energy $h\nu_\theta$, which means at a frequency ν_θ lower than ν_0. In other words, light waves by colliding with the free electron should be changed from a higher frequency to a lower, i.e., from blue toward red, and incidentally if such a change occurs it would be established that light travels in quanta, i.e., not as a continuous vibration but as a succession of what might be called packages of energy, like bullets issuing from a machine gun.

In Compton's experiments the primary radiation emitted by a molybdenum anticathode was scattered by charcoal or paraffin wax. The loosely bound valency electrons of the carbon then behave as though they were free and the secondary spectrum appears to be displaced in the direction of longer wave lengths with respect to the primary spectrum. In tests carried out at the Norman Bridge Laboratory for Physics at Pasadena, Calif., using aluminum as a scatterer, a Compton-effect photograph was obtained which showed both components of the α rays of molybdenum displaced by an amount which could be measured with an accuracy of about one per cent (as checked by R. A. Millikan) and within this limit the agreement with the displacement computed by the Compton equation was found to be exact. Several other investigators have obtained the Compton shift in wave length from a number of other elements besides carbon and have thus definitely established the reality of the Compton effect.

If the Compton effect is real, it means, in the first place, that light travels in quanta of action. In the next place, it means that each quantum has a definite amount of energy and also a definite amount of momentum. Furthermore, it indicates that as a result of collision, the quantum retains its speed but loses some of its size because of the lower frequency which it then possesses. Moreover (a proof of this is not given here because of lack of space) the fact that Compton's calculation of the displacement of the wave length is correct proves that the quantum obeys both the law of conservation of energy and, what is even more important, the law of conservation of momentum.

The next important development has to do with the atom model again.

The present article has presented an historical résumé of changes in the theories of radiation from that of Maxwell with the concept of a continuous process to that of Planck, Einstein, and Bohr with the concept of the discontinuous process involving quanta of action. That the quantum of action theory and the Bohr concept of the atom give a correct interpretation of radiation was established by Millikan, Compton, and others.

The next step deals with Sommerfeld's modifications of the Bohr atom model; and lest the readers' revised views sink into complacency, let him note that another article will introduce Schrödinger's wave mechanics and the matrix calculus of Heisenberg, developments of the past three years.

[7] Ibid., p. 213.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Fifth Report of the Steam-Nozzles Research Committee

PREVIOUS reports of this important committee were noted in MECHANICAL ENGINEERING as follows: vol. 46, no. 3, March, 1924, pp. 148–150; vol. 47, no. 9, September, 1925, p. 777; vol. 48, no. 2, February, 1926, pp. 171–172. These reports covered the account of tests on the efficiencies of convergent impulse nozzles and of two sizes of Parsons' reaction nozzles. All tests were carried out with superheated steam on both sides of the nozzles and in every case the pressure on the exhaust side was that corresponding to the atmosphere. Nozzles of various types with nominal angles of 20 and 12 deg. were tested. Fig. 2 gives the average energy efficiencies obtained with these nozzles and indicates the changes in energy efficiencies due to variations in angle-plate thickness and throat length as well as the effects produced by chamfer.

There are two main ways in which the efficiency of a steam nozzle may be determined directly by experiment; these are known as the reaction method and the impulse method. The Committee used the impulse method in which all the steam connections are rigid and the reaction of the nozzle is obtained from the impulse of the steam jet on a movable pressure plate. At first the results obtained by this method were inconsistent with those obtained by the reaction method. The first report, however, described the design of a pressure plate or rather a gage which succeeded in overcoming this anomaly. It was found possible with this apparatus to test the nozzle over a wider range of steam velocities than had been done hitherto. The theoretical steam velocities varied from 300 to 1600 ft. per sec. and over. It was found, however, that the degree of accuracy of the measurements fell off too much to make it worth while carrying out tests at velocities below 300 ft. per sec.

In the work covered by the first four reports, the back pressure against which the nozzles discharged had always remained at or near atmospheric pressure. The possibility of varying this pressure had been anticipated, however, when the apparatus was originally designed and the main casting which formed the exhaust chamber had been made to stand a pressure of 60 lb. per sq. in. gage in case pressures higher than atmospheric were needed. Suitable arrangements for lubricating the gland were also provided. In the present report are described data of efficiency tests made at the constant back pressure of 45 lb. per sq. in. The modified and enlarged apparatus and additional measuring devices are described in the original report.

Tests to Determine the Effect of Surface Finish

A factor which had not been investigated by the Committee in the work covered by their previous reports was the effect of surface finish on the efficiency of nozzles. The nozzles used in the Committee's tests had different degrees of surface finish. The steel partition plates of the curved impulse nozzles were left rough, in the state in which they remained after having been cast into the nozzle blocks. The Parsons' blading, on the other hand, had a smooth surface, caused by drawing the standard brass section through dies. The straight elementary nozzles were machine finished and the built-up type of impulse nozzles was also machined throughout. A feeling was expressed that useful information might be obtained if it were found possible to devise standards of roughness which could be applied to the inside of a nozzle, and the serrations of a standard Whitworth thread seemed suitable for this purpose. A single straight elementary nozzle was chosen for the first experiments on surface finish because this type lent itself most readily to an accurate reproduction of such threads, and because it had proved to be highly stable.

Two degrees of roughness were adopted. The first corresponded to the comparatively fine thread of 24 standard Whitworth threads per inch. The second was a much coarser thread, namely, 8 standard Whitworth threads per inch. The nozzles used for this purpose were duplicates of the $1^3/_8$-in. diameter single straight elementary nozzle.

It would appear from these tests that the effects of surface finish have a considerable bearing on the efficiency of these straight nozzles, in which, it should be remembered, the parallel throat portion predominates. It is quite possible for nozzles to deteriorate to a roughness equivalent to 24 threads per inch, though it is perhaps doubtful whether they ever get as rough a surface as is given by 8 threads per inch. The former represents a depth of groove from crest to root of 26.7 mils, whereas the latter is 80 mils deep, that is, three times the depth.

The effect of roughening the entry portion of the nozzle is more marked in the case of the finer-threaded nozzles than with those having the coarse-threaded surface. At a steam velocity of 1200 ft. per sec., for instance, the efficiency of the former with a smooth entry drops about 2 per cent, whereas if the entry is also roughened the drop in efficiency is twice as much. The coarse-threaded nozzle, on the other hand, is about 6 per cent less efficient than the smooth-bore nozzle at this velocity, and the fact that the entry was subsequently roughened has not made any appreciable difference.

Test to Determine the Effect of Dimensional Similarity

With the object of checking the effect of size on the shape and position of the velocity-coefficient curve, a single nozzle was made similar in dimensions to one of the seven $^1/_2$-in. diameter by $1^3/_4$-in. long nozzles, but the diameter was increased to $1^3/_8$ in. while the other dimensions including the radius at entry were increased in proportion. The larger nozzle had no flat surface surrounding its mouth, as was the case with the former nozzles, and the degree of machine finish on the inside surface was the same in both nozzles. In other respects the two nozzles were geometrically similar.

The test may (details in Table 41 and curve 41 in the original report) lead to the deduction that the velocity coefficient and therefore the efficiency of such a nozzle shape is not affected by its size in a wide velocity range.

Another series of tests was undertaken to determine the effect of the shape of the exit. The results were somewhat unexpected. Practically no difference in performance could be detected between the four nozzles, within the degree of accuracy of the tests. The average velocity coefficient for steam velocities beyond 800 ft. per sec. was 99 per cent, with a variation of not more than $^1/_4$ of one per cent. Below that velocity the general tendency of the

curves shows a rise, but too much stress should not be placed on individual points above 100 per cent, as tests at low velocities can only be considered as accurate to within 2 per cent. This uniform result points to the fact that any variation in efficiency to be expected in consequence of a difference in shape at the exit is nullified by a good convergence of the steam path up to the throat. Further tests have been devised and are in progress to investigate this point.

As to the main tests the following conclusion is quoted: The nozzles tested were convergent impulse nozzles with a nominal angle of 20 deg. Owing to the larger quantities of steam flowing through a nozzle under the higher pressure range, the height of these nozzles was reduced from 2 to $1^1/_4$ in. Otherwise they were commercially similar to those previously tested against atmospheric back pressure. The efflux angles of the new nozzles were found to agree with those previously determined, and the same settings in the tester were used. The addition to the apparatus of a gas-fired superheater brought the degree of superheat under control and, in the absence of any other criterion, the initial superheats in the new tests were adjusted to correspond with those of the old. This involved the use of higher initial steam temperature owing to the increased steam pressure. The degree of accuracy of the new tests fell off, and a considerable period elapsed before the pressure measurements could be considered to be reliable. The difficulty was eventually overcome by the provision of a mercury differential pressure gage, working under cool water. This gage was used in conjunction with carefully calibrated test gages of the Bourdon type. The tests showed no appreciable difference between the two pressure ranges. (*Proceedings of the Institution of Mechanical Engineers*, no. 1, 1928, Original Report, pp. 31–81; discussion (not abstracted), pp. 81–121, illustrated, *eA*)

Short Abstracts of the Month

AERONAUTICS (See National Defense: The Battleship Bubble)

A Giant Parachute

MAJ. E. L. HOFFMAN, Commandant of Wright Field, who last year was awarded the Collier Trophy for his efforts in the development of the parachute, has developed and is perfecting a mammoth parachute measuring 84 ft. in diameter, capable of supporting the weight of an entire airplane and bearing it safely to the ground.

Structurally it is a reproduction in all main respects of the man-carrying type, having a pilot chute, vents in the dome, the same weight and quality of silk, and the same type of shroud lines. There are a greater number of panels and shroud lines; 96 of the former, 48 of the latter. Many interesting tests have been performed with the new parachute. Twice it has successfully borne to the ground a 1600-lb. bomb from the bomb bay of a plane, circling at an altitude of several thousand feet. So great is the lift and strength of the chute, however, that it shows little tendency to deflate upon reaching the ground and, in the bomb test, caught by winds, dragged the great weight quite a distance across the field before it could be halted.

There is still much to be accomplished before the chute is ready for the final test of dropping with an airplane. A positive releasing mechanism, separating the weight and parachute upon landing, is in contemplation. This would eliminate the danger of dragging. Perhaps some quick deflation method will also be conceived. Major Hoffman is fully confident of the strength of the chute to support a weight equal to that of an airplane with passengers, and the dropping of an airplane with a parachute is, of course, not an unheard-of experiment. Two such drops have been accomplished in California. What Major Hoffman hopes to obtain is a parachute of such simple mechanism, ease of application, and reliability of operation as to be practical for all passenger planes, the type of chute that will be dependable when manufactured upon a production basis. (*Aero Digest*, vol. 13, no. 1, July, 1928, p. 124, *d*)

British Military Planes

AT THE Royal Air Force Display held on June 30, 1928, at Hendon, a number of types of military planes were shown. Obviously some types more or less known to exist were not shown as they belong to what is colloquially described as "hush-hush," but even those which were shown are sufficient to give a clear idea of what at least one European country has in the way of military aviation equipment.

Before describing the types themselves, some of the conclusions by Maj. F. A. de V. Robertson (*Flight*, vol. 20, no. 26/1018, June 28, 1928, pp. 484–486) may be mentioned.

The Air Ministry desires to have as few types as possible in actual service use, but at the same time it wants to keep alive by means of orders the aircraft firms on which the country depends for its air equipment in time of war, and also wants to promote the development of the art. Therefore, when two machines of equal merit are produced the probability is that orders for both will be given and some squadrons will be equipped with the one, and others the other. When a radical type of machine is produced such as the "Fox" with the Felix engine or the "Sidestrand" with twin Jupiters, the policy is to equip one squadron with the type and give it an extended trial.

As regards the fighter type of machine, views on its importance differ. Despite its name, the fighter is a defensive airplane and most of those used by the Air Force are capable of flying both day and night. In addition to this, there has been talk lately in British aeronautical circles of a new sub-class to be known as "interceptor" fighters. If any such machines exist they are still secret. It is probably a specialized type of fighter which would sacrifice some qualities, such as low landing speed and flight endurance, to enhance others, such as high speed and rapid flying. As regards their use the picture which comes to mind is that on receipt of a raid warning the interceptor fighters will go up very rapidly along the coast prepared for a short sharp fight with the raiding bombers.

The general-purpose airplane was developed for work overseas where no enemy aircraft is expected to be encountered and where, therefore, specialized types are not necessary.

Among others the following planes were in the display. They are briefly listed as stated above to give an idea of the state of development of British military aviation.

SINGLE-SEATER FIGHTERS

The Boulton-Paul "Partridge" is an all-metal machine fitted with Bristol Jupiter-7 engine. The Bristol "Bull Dog" is also an all-metal machine.

The Hawker "Hawfinch" is remarkable for its compactness and unusual in that it is a two-bay biplane with pronounced stagger which gives an excellent view.

The Westland "Wizard" is a parasol monoplane fitted with the new Rolls Royce F-XI water-cooled engine.

BOMBING AIRCRAFT

The Boulton-Paul "Sidestrand" has a fuselage of tubular construction with locked-joint-type tubes. The joints between the longerons and struts are made by bolting, magnesium alloy

"pads," with flat faces on their outer sides being slipped over longerons and strut ends. It has two Jupiter-6 engines mounted outboard on the lower wing on steel-tube structures designed to avoid placing torque reaction stresses on the wing spars.

The Fairey "Fox" is a high-performance, light, day bomber in which all projections on the fuselage have been suppressed to increase the aerodynamic efficiency. This has been helped by the use of a Felix D-12 engine which has a very small frontal area. A further saving in parasite resistance has been effected by fitting a surface radiator in addition to the retractable radiator.

The fuselage is arranged so that the gunner can lie prone when bombing, a trap door in the floor of the fuselage giving him a clear view. The bomb release gear is placed close at hand on the starboard side. For tail defense of the machine the "Fox" is fitted with special mounting for the after gun and the gunner is shielded by the wind screen and is thus able to operate his gun, which covers the entire field upwards and aft.

The Fairey engine weighs 300 kg. or 660 lb. and develops normally 430 b.hp. at 2300 r.p.m. The engine is very carefully cowled in, and the various auxiliaries are driven direct, thus eliminating the resistance of wind-mill drives. The cooling system is so arranged that when starting up, hot water from the cylinders is bypassed to the oil temperature regulator and thereby rapidly heats the oil. In practice the throttle can be opened up after five or six minutes so that one of the objections to water cooling is greatly reduced.

Troop and Torpedo Carriers

Of the troop carriers, only the Handley Page "Clive" was shown. Of the torpedo carriers only the Blackburn "Ripon" was shown and it did not demonstrate how it drops its torpedoes.

Civil Aircraft

A number of interesting civil aircraft machines were also shown. Mention will be made here of only the most important or unusual.

The Vickers "Vellore" is of all-metal construction and designed as a freight carrier. As such a machine does not need to be particularly fast, the wing area was made very large, but the larger the area for a given weight, i.e., the lower the weight carried per square foot of lifting surface, the greater load can be carried with a given engine.

The Avro "Buffalo" is a two-seater torpedo-carrying and bombing aircraft fitted with a Napier Lion Series-XI engine. This machine is specially designed for operation from an aircraft carrier. The controllability is said to be particularly good and the fuselage decking and nose shape are so formed as to give the best view to the pilot, both for deck landing and torpedo sighting. A bombing station is provided in the floor of the fuselage so that the observer can lie prone and sight through a large sliding window in the bottom of the fuselage.

The Beardmore "Inflexible" is one of the largest machines actually flying. It has a wing span of 158 ft. and a weight of more than 15 tons. The machine is a high-wing monoplane and should be efficient aerodynamically. The large span assisted in reducing induced drag while the fuselage in spite of its actual size forms a very small percentage of the wing span. It is driven by three Rolls Royce Condor engines of 700 hp. each. The machine is equipped with a servo rudder of the Flettner type. The pilot operates the servo rudder which under the action of the air forces upon it actuates the main rudder. Of the three Rolls Royce engines, one is mounted in the nose of the fuselage and the other two are slung under the wing some distance outboard.

Another huge machine is the Blackburn "Iris-II." This also has an all-metal hull and is driven by three Rolls Royce Condor engines. The wing span is 95 ft. 6 in. and the total weight empty is 17,350 lb., while the total loaded weight is 27,000 lb. The wings are of biplane structure braced in two bays on each side of the center planes. It is a reconaissance and coastal patrol machine with bomb racks and machine guns.

Reference has already been made to the Boulton and Paul "Sidestrand." It is an all-metal three-seater high-performance bomber with two Bristol Jupiter-6 radial air-cooled engines. It is capable of developing 130 m.p.h. at 5000 ft. elevation and to climb to 10,000 ft. in $10^1/_2$ min. It has a service ceiling of 21,500 ft. and a range at full throttle of 750 miles. In addition to the bomb racks the "Sidestrand" carries machine guns in the forward gun turret in the nose and on the aft turret behind the wings.

A two-seater dual-control Autogiro was shown powered with a 180-hp. "Lynx" engine. A more or less standard type of this peculiar machine has been evolved, combining the advantages of safety which are characteristic of it with performance possibilities of the ordinary fixed-wing aeroplane. It has a maximum speed at sea level of 100 m.p.h. and a minimum speed of 25 m.p.h. The endurance at cruising speed is given as 3 hr.

The deHaviland "Hound" is a general-purpose two-seater fighter fitted with a Bristol Jupiter Mark VIII engine and carrying one Vickers machine gun for the pilot and one Lewis machine gun mounted on a special D-H ring for the gunner. The wings have duralumin oval tubular bars and steel tubular underplane and drag struts. The speed at 6000 ft. is 156 m.p.h. and the landing speed is 57 m.p.h. The climb is $8^1/_2$ min. to 10,000 ft. with a service ceiling of 24,000 ft. and cruising range 1000 miles.

Reference was made above to the "Lynx" engine. It is an Armstrong-Siddeley machine and is of the seven-cylinder type with one inlet and one exhaust valve per cylinder and a single-throw hollow crankshaft balanced by a gun-metal weight fitted to each web. (The above abstract was made up from several articles in *Flight*, vol. 20, nos. 26/118 and 27/119, June 28 and July 5, 1928, together with some additional information available to the abstractor, *gd*)

The Armstrong-Siddeley Leopard Aero Engine

THE 700–750-hp. Armstrong-Siddeley Leopard engine has been designed and developed by Armstrong Siddeley Motors, Ltd., of Coventry for use in torpedo, heavy bombing, and load-carrying aircraft, and is believed to be the most powerful air-cooled engine in production in the world.

The general lay-out and design follows very closely that of the same company's well-known Jaguar engine, and consists of two "banks" or rows, each comprising seven cylinders mounted radially on the crankcase.

The principal departure from the Jaguar design is that the induction fan is geared to run at a higher speed than the crankshaft in order to obtain a better volumetric efficiency, and that four valves are fitted to each cylinder instead of two, this being rendered necessary by the increased cylinder capacity.

Two inlet and two exhaust valves per cylinder are operated by rockers which pivot on two spindles mounted on the cylinder head. These spindles are anchored at their rear ends to the top of the head; their front ends are supported by a compensating bracket, which is anchored to a point near the bottom of the cylinder head.

The valve rockers are operated by push rods and tappets from the cam drum which is inside the front portion of the crankcase. Tappet clearance adjustment is provided in the push rods.

The cam drum has three inlet cams and three exhaust cams and rotates at one-sixth crankshaft speed. Rollers and tappets transmit the cam motion to the push rods. The pistons are machined all over from "Y" alloy forgings. Each carries one scraper and two compression rings, all three rings being above the

piston pin. The piston pin floats in the piston and connecting-rod bushing and is located endways in order to prevent scoring the cylinder walls.

The crankshaft is made in one piece and has two throws set 180 deg. apart, each crankpin carrying one master rod and six auxiliary connecting rods. It is hollow and serves the purpose of distributing the lubricating oil. It is carried by two large roller bearings, one just behind the rear crank throw and the other just in front of the front crank throw.

The crankshaft, beyond its front roller bearing, carries the timing gear and cam drum, a bevel gear (which drives the oil pump, magnetos, gas distributor and C.C. gun gear), and the airscrew thrust bearing. The rear end of the crankshaft carries the spur gear which drives the induction fan. The front and rear webs of the crankshaft are counterbalanced.

Mixture is supplied to the engine by a Claudel-Hobson carburetor through an induction fan which delivers the mixture into an annular induction casing. Thence the mixture passes to the cylinders by means of induction pipes. Experiments have proved that the use of an induction fan of this kind considerably increases the volumetric efficiency of the engine and gives a perfectly even distribution to all cylinders.

The carburetor is supported on an induction elbow attached to the rear end of the engine, the controls and air-intake pipes being integral with the carburetor and engine. (*The Aeroplane*, vol. 34, no. 25, June 20, 1928, pp. 886 and 888, 2 figs., *d*)

ENGINEERING MATERIALS

New Plastic

THIS particular plastic is of interest because it is produced from two food products which in the past have been wasted. One of these products is casein and the other is furfural. Furfural a few years ago was merely a laboratory curiosity. Research work carried on chiefly by the Miner Laboratories in behalf of the Quaker Oats Company has led to development of production by virtue of which furfural can now be obtained in tank car loads. Heat and pressure cause a reaction between the casein and the furfural, the latter acting in a manner somewhat analogous to formaldehyde. It is claimed that the resulting product is more waterproof than other protein aldehyde compounds and the resistance to moisture may be improved by adding certain materials to the furfural. The molding time is said to be much shorter than for other protein aldehyde compounds and articles can be molded to form, there being practically no shrinkage or distortion. (*Plastics*, vol. 4, no. 2, Feb., 1928, pp. 80 and 93, *d*)

FOUNDRY

Influence of the Addition of Coal Dust to the Cupola

A CERTAIN percentage of coke, say 12 per cent, is replaced by coal dust introduced before the tuyeres. It is claimed that considerable local heat caused by the rapid consumption of the coal dust benefits the melting zone of the furnace and that the concentration of heat caused by the combustion of coal dust produces a more rapid melting of the iron charged. It appears that disturbances due to incorrect introduction of the tuyere blasts are largely compensated at the same time, and that there is a saving in the total fuel used.

The details of the process are given in the original article, as well as some data of tests. Rather surprisingly it is claimed that less absorption of sulphur by the iron takes place. The most radical improvement due to the coal dust is indicated by the changes in the composition of the flue gases as given in the table in the original article. From this it would appear that with coal dust there is an increase in carbon dioxide varying from 4 to 8 per cent and a decrease in carbon monoxide at times as high as 45 per cent. (Dr. of Engineering, P. Bardenheuer and Dr. of Engineering, A. Kaiser in *Iron and Steel Industry*, vol. 1, no. 4, January, 1928, pp. 103–104, *ed*)

FUELS AND FIRING

The Present Position of Colloidal Fuels and Coal-Oil Amalgams

COLLOIDAL fuel was developed in America during the War, and consists of oil with a certain amount of pulverized coal suspended in it and a material referred to as "fixateur" (ordinary soap or lime rosin soap) used to help the coal stay in suspension. The name colloidal fuel is not exact, as the coal is never pulverized to the fineness permitting a true colloidal suspension. This fuel is not used any more at all because of economic conditions. In America, oil is so cheap that it does not pay to add pulverized coal to it, and in England it is too expensive.

The amalgams are, in this case, a soft pasty mass representing a conglomeration of very small balls, as a rule about $^1/_8$ in. in diameter, held together by some mineral oil or other liquid hydrocarbon. The most important development in this connection was the Trent process. Four or five very large plants, among these one in France, were erected to operate on this process, but all have closed down as the process could not compete in price with other fuels.

W. E. Trent is also working in another very interesting field, that is, extremely fine grinding of coal to a degree which may be termed "semi-colloidal." That is to say, instead of using pulverized coal for combustion or carbonization without any oil admixture, at, say, 90 per cent through a 100-mesh screen and approximately 65 per cent through a 200-mesh screen, he grinds it much finer, at least equivalent to all through a 400-500-mesh screen, and even as fine as 750-1000 mesh. When coal is obtained in this condition it possesses remarkable physical properties, running up and down tubes and over weirs, and finding its own level exactly the same as a liquid.

For this purpose a special type of retort has been designed which is like a vertical tubular condenser, in which the pulverized coal flows down the inside tubes and up other tubes, which are externally heated, flowing out at the side of the setting in a continuous stream of carbonized fuel, with recovery of the by-products in the ordinary way, while the residual solid fuel is, of course, available for use at burners. (David Brownlie in *Engineering and Boiler House Review*, vol. 41, no. 12, June, 1928, pp. 582 and 585, *d*)

Pulverized-Lignite Experiments

DATA of tests carried out at the University of North Dakota on a Babcock & Wilcox type of boiler with 2400 sq. ft. of heating surface. The furnace was designed for burning pulverized lignite and was equipped with a burner of the fishtail type. A "Unipulvo" pulverizer rated at 2000 lb. of soft coal per hour was used. For comparative tests there was available another Babcock & Wilcox boiler of a somewhat different type and about the same size, but equipped with a semi-Dutch-oven type of furnace. The coal was used raw, as the dryer was not ready for operation. The first attempts to operate the pulverizer on raw lignite were unsuccessful. Preheated air was then drawn through the pulverized chamber along with the air supplied.

Among other things, it was found that the moisture content of the dust produced for any given outlet temperature decreases with decrease in the size of lignite as fed. Certain changes had to be made in the pulverizer and pulverizing chamber because of conditions of operation. Tests of the installation indicate

that the power consumption in pulverizing lignite depends on a number of factors such as temperature, moisture content, size of the lignite entering the machine, volume and initial temperature of the air used for removing the dust from the pulverizing chamber, and many others.

The average power consumption per ton of lignite pulverized was 21.8 kw-hr.; the power consumption per ton of Pocahontas screenings was 20.4 kw-hr. A comparison based on heat value of the fuel pulverized shows a total liberation of 618,900 B.t.u. per kw-hr. for the lignite and 1,389,200 B.t.u. per kw-hr. for the Pocahontas coal.

Boiler tests were conducted as nearly as possible in accordance with the 1923 Power Test Code of the A.S.M.E. Uniform operating conditions at or above normal boiler rating could be obtained only when the outlet temperature was above 100 deg. fahr. The operation of the furnace was found to be dependent upon the slagging of the ash. Complete combustion could be obtained with slight excess of ash but the relatively low fusion temperature of the ash required admission of sufficient excess air to prevent slagging. The average rate of fuel consumption maintained in the boiler test was 2.44 lb. of lignite as fired equal to 16,540 B.t.u. per cu. ft. of effective furnace volume. (R. L. Sutherland, N. T. Bourke, and E. J. O'Keefe, College of Engineering of the University of North Dakota in *Power*, vol. 67, no. 26, June 26, 1928, pp. 1141–1144, 5 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING

New Method of Atomization in Gasoline Engines

IN THE new Stewart-Warner fuel-supply system, the conventional carburetor has been completely eliminated and a direct-feed fuel system substituted.

The fundamental principle of the direct-feed fuel system is to atomize and vaporize the fuel thoroughly before finally mixing it with a sufficient quantity of air to form a combustible mixture, thus giving a dry, cool gas. To do this the carbureting action is transferred to the main fuel tank. A semi-vaporized non-combustible mixture of air and atomized fuel is brought forward to an exhaust-gas stove where the heavier ends are evaporated. The correct amount of air is added at the intake manifold inlet. Throttle valve and inlet manifold remain the same, both as regards function and location, except that the manifold has no hot spot.

By performing the preliminary carbureting action at the fuel tank, only a slight inlet-manifold vacuum is necessary to bring the mixture to the inlet manifold. Mounted at the inlet of the intake manifold is a mixing chamber incorporating a spring-seated air valve balanced by means of a dashpot. About four-fifths of the mixture entering the manifold represents cold air admitted through this valve, the other fifth being a non-combustible mixture of gasoline vapor and hot air which enters the mixing chamber around the outside of the venturi through a pipe under direct suction from the intake manifold in proportion to the air velocity. For the full vaporization of the fuel in this mixture a stove is provided.

The exhaust pipe passing through this stove has walls only about 0.015 in. thick, so the heat can flow through them readily and cause the vaporization of the heavy ends. The lighter ends of the fuel have already been vaporized during the passage through the $^3/_4$-in. tube from the fuel tank at the rear. The method of fuel admission at the tank to the air in this pipe is very simple. The inlet air pipe passes down into a container in the gas tank and is equipped with two venturis, in each of which are located gasoline jets, the lower one being for low- and the upper for high-speed operation. A constant level is maintained in this compartment by a simple poppet valve operated by a cork float, the function being similar to that of the carburetor float.

It is claimed that the mixture in the pipe line is non-combustible and that a better fuel economy is obtained with this device than with the standard carburetor. (A. F. Denham in *Automotive Industries*, vol. 58, no. 26, June 30, 1928, pp. 1004–1006, 3 figs., *dA*)

Coal-Dust Diesel Engine

IT WILL be recalled that the first engine built by Rudolph Diesel himself was to run on coal dust. It was, however, entirely unsuccessful, whereupon the Krupp and the M.A.N. companies undertook its further development along the lines which have since become conventional, namely oil fuel and outside atomizing air compressor. The most important change in the original Diesel was the development of solid injection; and now comes a return to the original Diesel idea in the form of the pulverized-coal engine.

In 1911 the Kosmos Machine Works of Goerlitz, Germany, began experimenting on such an engine but did not produce a really workable unit until 1916; at that time a ten-year-old M.A.N. single cylinder $16^1/_2 \times 25$-in. four-stroke-cycle engine was converted to use the new fuel. It is stated that the engine has been in regular operation ever since and is furnishing power to the factory. The wear on the cylinders is well within the permissible commercial limits and in fact it is still operating with its original piston and cylinder lining and the cylinder has not been rebored. The piston rings have operated from 1916 to 1924 and had been replaced then. The engine still obtains its initial compression of 440 lb. absolute, notwithstanding the fact that for twelve years it is said to have operated with nearly all grades of German anthracite and can operate also on oil or a mixture of oil and pulverized coal. It will run also on turf, saw-dust, charcoal, rice-dust, flour, and even coke.

The operation of the engine is described substantially as follows: The required amount of pulverized coal for the working stroke is segregated by the governor and is injected by pressure into the compressed combustion air inside of the cylinder which is at a pressure 440 lb. absolute. This takes place within a "hurling" chamber located ahead of the cylinder. This chamber may be permanently open to the cylinder or it may be connected with the latter through an admission valve, both methods having proved equally successful. Contrary to the Diesel engine the pulverized-coal engine compresses the fuel and combustion air simultaneously but keeps them separated until ignition occurs. (It is not clear how this is done when the hurling chamber is permanently open to the cylinder.—Editor.) Therefore it avoids the difficulty of the Diesel cycle in that the incoming fuel oil must be heated and ignited in an extremely short period of a fraction of a single stroke. The pulverized-coal engine extends this time to at least one full stroke, making it about 10 to 15 times as long as in the conventional Diesel engine.

No ash must be permitted to penetrate between the piston and cylinder wall, as otherwise it would get into the lubricating oil. This was originally taken care of by admitting clean compressed air at 880 lb. pressure between the piston rings immediately before ignition takes place, thus providing an air seal. Another method, not described, of sealing the piston rings has been devised, however. The pulverized-coal engine consumes more lubricating oil than a Diesel engine. As regards fuel consumption, it was found on brake tests that the engine consumes about 0.13 lb. of oil per hour or about 8000 B.t.u., equivalent to 0.91 lb. of brown coke. In this way a brake horsepower-hour can be delivered at the cost of 0.12 cents with pulverized coal and 0.45 cents with oil (in Germany). The author particularly emphasizes the absence of prohibitive wear of the engine due to the use of pulverized coal. A conservative estimate indicates that the engine

has been in actual use with pulverized coal for 9000 hours and is still in operation.

The coal must be at least as finely pulverized as that required for boiler-furnace firing and the degree of fineness must be increased when dealing with low-volatile high-ash coals. Experiments have shown that coals that are hard to ignite can be burned successfully but that better results are obtained if they are ignited with gasoline or activated coal during the brief time allowed for ignition. (R. Pavlikowski in *Power*, vol. 68, no. 4, pp. 136–138, 4 figs. including 2 indicator diagrams, *dA*)

LUBRICATION

Spread of Lubricants Over Solid Substances

THE author deals here primarily with the behavior of lubricants at very low and very high temperatures. The problem is particularly involved for these latter. For his tests, he used olive oil with 1.25 free acidity, mutton grease with free acidity 0.03 per cent, and a neutral saturated mineral oil of specific density 0.8647 at 15 deg. cent., and a coefficient of absolute viscosity of 0.0785 at 50.2 deg. cent., and 0.0024 at 100 deg. cent.

In the first test the behavior of the lubricants on soft steel was studied and it was found that fatty oils spread much more rapidly on machined surfaces than do mineral oils when deposited on steel neutralized by a skin of stearic acid. The mineral oil at first stays where put but at the end of several hours the droplets begin to flatten and the diameter to increase; they then spread slowly, and ultimately the entire surface is covered. This spreading always takes place in an atmosphere saturated with oil vapors no matter whether the drops be small or large and notwithstanding the presence of an excess of stearic acid which proves that this spreading is not due to the evaporation of the underlying skin.

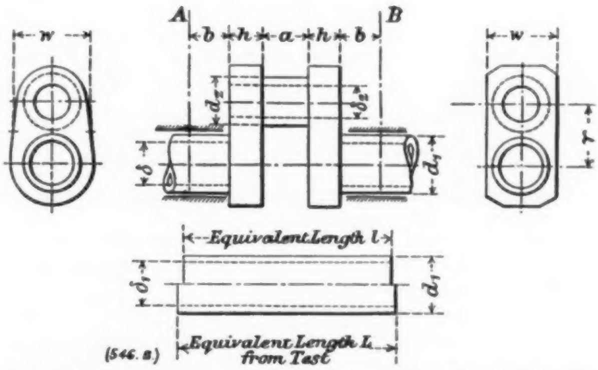
It is also claimed by the author that the progressive expansion of the drops is not due to the marginal solution of the skin in the hot oil. He proves this in the following way. He sets up at first a surface of neutralized steel without, however, depositing on it any oil; if now, say, after twenty-four hours droplets of oil be deposited on the surface, it is found that this surface resumes its activity and the oil expands without hindrance. The author believes that this phenomenon is due to the slow superficial attack of the steel by the skin and that the soapy material formed by the first molecular layer dissolves in the excess of neutralizing matter, finally producing a layer of molecules lacking in the characteristics of polarity and orientation. Special experiments have shown that at 100 deg. cent. stearic acid attacks steel. Notwithstanding the higher temperature of melting of these bodies, other materials such as lacceroic acid and melissic acid dissolved in trichlorethylene, when used as a neutralizing material, behave in the same manner as the stearic acid. Acids with an even number of carbon atoms resist best and the carboxyl group plays an important part in this reaction.

The author used several other materials in place of steel. The expansion of the drops of oil on tungsten noticeable at room temperature is very rapid at higher temperatures which he explains by the fact that tungsten with its four or five valences probably causes a free orientation of the skin. In all metals the phenomena of expansion appear to be most active on cold-worked metal surfaces, such as thin rolled sheets. The oil stays in drop form or expands only slightly on gold, polished platinum, and several other materials. On electro-deposited chromium and nickel the drops stay. On nickel in particular, the oil may remain for indefinite periods, such as 200 hours or more, and does not spread until a temperature is reached above 100 deg. cent. (Paul Woog in *Comptes Rendus des Séances de L'Académie des Sciences*, vol. 186, no. 2, January 9, 1928, pp. 71–73, *e*)

MECHANICS

An Empirical Formula for Crankshaft Stiffness in Torsion

THIS formula was evolved from the results of stiffness tests on certain crankshafts. Subsequently the necessary data for checking purposes became available as data on the stiffness of two machine shafts were determined by the Admiralty by twisting scale models. Three other marine shafts were tested for stiffness by the New York Navy Yard, the results having been published by Prof. F. M. Lewis in a paper before the Society of Naval Architects and Marine Engineers in 1925. The stiffness of several aircraft shafts was determined—one by the manufacturers and the others by the Air Ministry, etc. In all cases the shafts were twisted in bearings with clearances approximating those used in ordinary working and all stiffnesses relate to transmitted torque. The author gives a table containing the formula reproduced in Fig. 1.



Equivalent Length from A to B in Terms of Journal Shaft. $= l = (2b + 0{\cdot}8h) + \frac{3}{4}\left(\frac{d_1^4 - \delta_1^4}{d_2^4 - \delta_2^4}\right)a + \frac{3r}{2}\frac{(d_1^4 - \delta_1^4)}{hw^3}$

$$\frac{l}{d_1} = P + Q + R$$

Corresponding Stiffness from A to B $= \frac{GJ}{l}$

where $G = 11{\cdot}8 \times 10^6$ lb. per sq. in. for steel.

and $J = \frac{\pi}{32}(d_1^4 - \delta_1^4)$.

FIG. 1 SUGGESTED EMPIRICAL FORMULA FOR CRANKSHAFT STIFFNESS IN BEARINGS

The formula for the equivalent length of journal shafting comprises three terms:

(*a*) The first term represents the stiffness of the journal shafting increased by an ordinary amount 0.8 *h*, to take approximate account of the local yielding of the webs at the points of juncture with journals and crankpins.

(*b*) The second term is proportional to the equivalent length of the crankpin with full torque transmitted through it.

(*c*) The third term is proportional to the twist which would result from the bending of the webs in their own plane in transmitting a pure torque with no bearing restraints (so that one journal becomes displaced laterally in relation to the other) if simple beam equations were applicable.

Although the several terms have the foregoing significance the formula is not rational, and indeed having regard to the proportions of the shafts, the complexity of form in many cases, and the obscure restraints offered by the bearings, it is not to be expected that a simple rational formula can be obtained; nor, for many practical purposes, is such a formula needed.

The general form of the author's equation was obtained by

treating the crank as being unrestrained by bearings and subjected to a pure torque at points A and B. Subsequently, the numerical coefficients of the three terms, namely, unity, $^3/_4$, and $^3/_2$, were determined by trial and error. An attempt was made at first to determine the best values for these coefficients by treating them as unknowns in simultaneous equations, which were solved in groups of three, but the values given by the groups differed considerably and averaging the respective values was not satisfactory; moreover, to adopt any value other than unity for the coefficient of the first term would be anomalous.

It should be observed that, in the ideal case, the ratio of the rigidity modulus to Young's modulus is included in the coefficient to the third term, but, as this ratio is sensibly the same for all materials of which cranks are made, the formula should not need to have the third coefficient modified according to the material.

A comparison of corresponding quantities derived from the formula and from tests indicates a very good agreement, the variation seldom exceeding 10 per cent and being usually considerably below that. An examination was also made of the effect of crank dimensions on stiffness. Among other things, the author calls attention to the large influence on stiffness of the web width w. This would indicate that crank stiffness may be increased economically within limits by increasing w which is an argument for disk webs where high stiffness is required.

Application of the author's formula to torsional resonance is briefly considered. (B. C. Carter. Paper published by permission of the Director of Scientific Research, Air Ministry, in *Engineering*, vol. 126, no. 3261, July 13, 1928, pp. 36–39, 2 figs., *teA*)

NATIONAL DEFENSE

The Battleship Bubble

THE FIRST of a series of articles dealing with the subject of the battleship as a weapon of national defense. The author claims that the modern battleship is quite vulnerable to aircraft attack. While it is powerfully protected in the part above the water which gives it an appearance of impregnability, it is actually very weak in regard to under-water attack, as over 75 per cent of the outer skin of a modern battleship *is of steel no thicker than five-eighths of an inch.*

Attempts have been made to reinforce this under-water skin by means of the so-called blisters or bulges. As originally designed the bulge was a thinner plating built out from the hull of the ship on both sides and formed a series of inner-divided compartments. Naval opinion itself is divided on the protection afforded by the bulge. It does, however, give some protection if only because it gives more compartments. The author cites, however, the experience of the German battle cruiser *Lutzow* in the battle of Jutland, which would indicate that even bulkheads afford no certain protection, for if the ship is sunk deeply enough or is rolling or pitching in a heavy sea, the pressure of the water alone will burst bulkhead after bulkhead as they are not braced by the cross frames.

The author cites a number of instances of destruction of battleships and points out the weak spots that these showed. He refers, in particular, to the case of the old American battleship *Alabama* sunk during the air bombing test in 1921. The Navy claimed that the *Alabama* was sunk by a 2000-lb. bomb that struck near the main mast, while the Aircraft people contended that it was sunk by the bomb that fell 40 ft. away. When the *Alabama* was raised it was found that the hole was below the water line and measured 78 ft. long and 47 ft. wide, or enough to sink any battleship. (Cy Caldwell, *Aero Digest*, vol. 13, no. 1, July, 1928, pp. 33–35, and pp. 180–182, *g*)

POWER-PLANT ENGINEERING

Benson High-Pressure Boilers

THE original experimental Benson high-pressure boiler was described in MECHANICAL ENGINEERING (vol. 46, no. 5, May, 1924, p. 288; vol. 47, no. 5, May, 1925, p. 358; and vol. 49, no. 7, July, 1927, pp. 807–809). It was then stated that the larger boiler was under construction. This has now been installed in the boiler plant of the Gartenfeld Cable Works of the Siemens-Schuckert Company. This boiler has a nominal capacity of about 55,000 lb. of steam per hour. The steam is generated at the critical pressure but throttled to about 2550 lb. per sq. in. for use in the turbine.

The feedwater is fed into the system at 3400 lb. pressure by means of a high-pressure pump through a distributing header located above and on the central axis of the combustion chamber. From there it is supplied to the tube elements which form the furnace walls. Here the water is heated, saturated steam is formed, and some superheating takes place. The superheated steam returns to a second header, which supplies four of the superheater chambers located in the second pass. The remaining four superheater sections are used to reheat at 525 lb. some of the exhaust steam from the high-pressure section of the turbine.

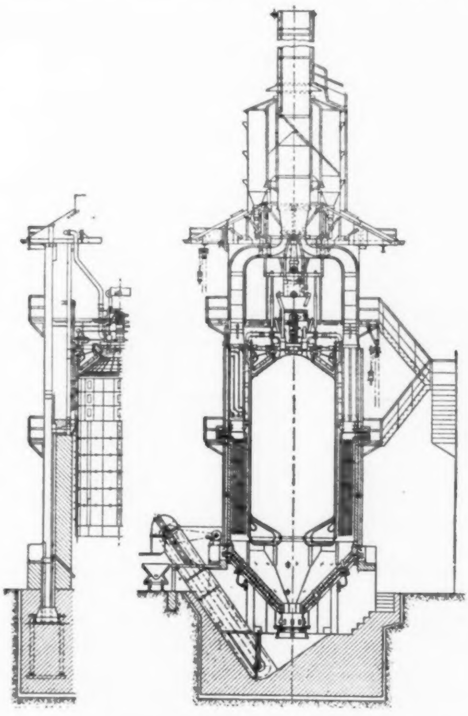


FIG. 2 SECTION OF THE NEW BENSON BOILER

Eight burners located at the top and arranged concentrically around the central axis of the boiler are provided. Four of these are for pulverized coal and four are oil burners used for starting. Since little attention is required for the boiler and the construction is such as to form a closed tower, a boiler house is superfluous and the boiler appears as an isolated structure looking somewhat like a water tower (compare Fig. 2). The plant is controlled either automatically or by pushbuttons from a control room located some distance away in the machine shop. Pyrometers are installed for each of the eight tube elements and an increase in temperature is an indication that the soot blowers should be

operated. Scale does not form in the tubes because no formation of steam bubbles takes place there.

Fundamentally, the flow system of the cable works plant is shown by the diagram, Fig. 3. Steam generated in the boiler (*a*) is delivered to the high-pressure section of the turbine at 2550 lb. pressure, to be expanded to 525 lb. Part of the discharge of the high-pressure turbine is reheated and passed to the low-pressure element (*b*), while part of it is used for process work in S_1. Any possible excess steam is stored in the Ruths accumulator (*k*).

Exhaust from the low-pressure element at 80 lb. is used for process work in S_2 and S_3. Condensate from S_2 is contaminated with acid and cannot be returned, so that the makeup must be supplied to the system from the evaporator (*g*) operated on steam bled from the low-pressure element of the turbine. Drains from the process equipment and evaporator return to the hot-well (*q*) from which the boiler feed pumps take their suction.

Heat requirements of the cable works were such that design problems were difficult. The largest part of the steam is required at 80 lb., 465 deg. fahr., with a somewhat smaller demand for steam at 295 lb., 465 deg. fahr. The steam delivery from the boiler plant

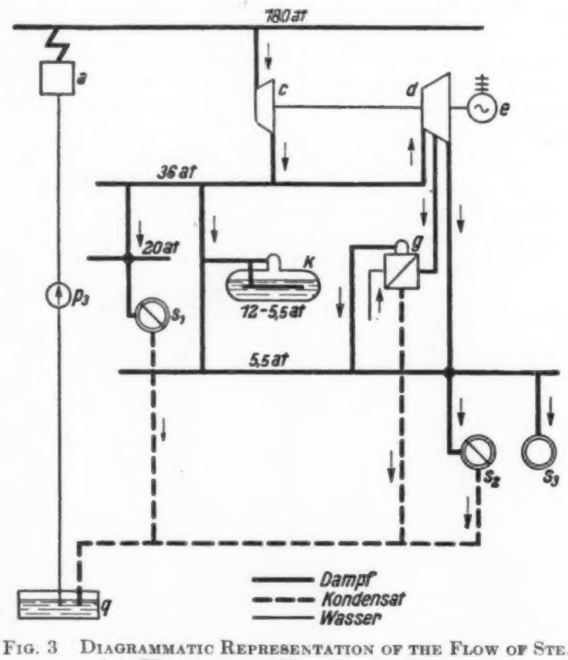


FIG. 3 DIAGRAMMATIC REPRESENTATION OF THE FLOW OF STEAM AND WATER IN THE NEW BENSON BOILER
(*Dampf* = steam, *wasser* = water.)

for process work must be maintained at the same temperature and pressure even though the turbines are shut down. Because of this, the actual plant design is intricate, requiring a great deal of apparatus which is not concerned with the Benson process proper and is not required with a normal power plant. (*Power Plant Engineerimg*, vol. 32, no. 13, July 1, 1928, pp. 718–720, *b*)

Industrial Process and Power Combinations

ONE of the important problems in laying out a plant where a considerable amount of power is required simultaneously with a large supply for process work is to decide on the method to be used for reducing the pressure between power steam and process steam.

Pressure drop cannot be eliminated, but it can be considerably minimized by a careful design and layout of the process mains and in the design of valves and fittings themselves. In fact, the complete arrangement and design of piping should be left to a reliable firm and their guarantee regarding the maximum pressure drop should be obtained—a guarantee which should also be contributed to by the valve makers.

The reducing turbine offers considerable advantage compared with the back-pressure engine. First, the mechanical losses and radiation losses are not more than 2 per cent for the former, while the losses inherent in the latter cannot be reduced below 5 or 6 per cent at the least, and in engines with a relatively high back pressure the losses become correspondingly greater. In certain cases the combination of a high-pressure engine and process scheme offers an advantage chiefly because the engine is more effective in dealing with high-pressure steam than the turbine, but this advantage is usually counterbalanced by the presence of oil in the steam and in the condensate.

This problem of choice can, perhaps, be considered by a comparison of actual results; these are based upon a common initial pressure of 180 lb. per sq. in. and a steam temperature of 530 deg. fahr. with a process-steam pressure of 20 lb. per sq. in., and where 70 million B.t.u. of heat per hour is required for process work and 1000 kw. to operate the plant.

Case 1—Steam from the boiler at the initial pressure is passed through a reducing valve to the process, the 1000-kw. of power being purchased from an outside source.

Case 2—A 1000-kw. back-pressure engine of 65 per cent Rankine cycle efficiency is used, any deficit in the process-steam supply being made up by high-pressure steam passed through a reducing valve.

Case 3—A 1000-kw. reducing turbine having the remarkably low efficiency of 50 per cent compared with the Rankine cycle.

Then, neglecting radiation losses, we have the following conditions:

	Case 1	Case 2	Case 3
Steam per hr. for power (lb.)..		39,600	51,500
Heat in steam per hr. (B.t.u.).		50,768,000	66,024,000
Heat in process steam per hr. (B.t.u.).................		44,944,000	61,926,000
Heat required from reducing valve (B.t.u.)...........	70,000,000	25,056,000	8,074,000
Total heat required from boilers (B.t.u.)..............	70,000,000	75,824,000	74,098,000
Extra fuel required in lb. per kw-hr..................		0.616	0.433

Thus the turbine arrangement offers an advantage in fuel economy alone equal to 44 per cent when compared with the engine scheme, and for an 8.5 per cent increase in fuel consumption by the boilers 1000 kw. of electrical power is generated compared with the reducing-valve scheme of Case 1. (W. S. Findlay, in *Power Engineer*, vol. 23, no. 266, May, 1928, pp. 165–166, 2 figs.)

Fish in Circulating Water of a Condenser

THE sub-title in the original is "A Fish Story." It would appear that minnows in the circulating water are actually affecting the heat transfers in condensers at the Crawford Avenue Station of Chicago Commonwealth Edison Company. The turbine there is a 50,000 kva. Parsons unit with an average steam consumption of about 8 lb. per kw-hr. The circulating water used by the condensers is at present 60 lb. per lb. of steam condensed. If, however, the specific heat of the water should be decreased in any way, more water would be required, and it is claimed that the presence of minnows in the circulating water causes a decrease of the specific heat.

Condenser water for this station is taken from the Drainage Canal. This water passes through screens which keeps out many of the minnows. In all the fall and winter months the water is colder and the tiny fish are more aggressive. In this

way they are more apt to go through the screens. Neither the number of the minnows nor the average specific heat of fish appear to be fully established. The author gives, however, a calculation from which it would appear that the presence of the minnows means a loss of close to three-quarters of a million gallons of water per day.

The article appears in a paper published by the College of Engineering of the Armour Institute of Technology. An abstract is given on the assumption that it is a real investigation and not intended as a joke. (*The Armour Engineer*, vol. 19, no. 3, March, 1928, pp. 89 and 106, 1 fig., *d*)

RAILROAD ENGINEERING

Locomotives for 700-Lb. Steam Pressure

THE Swiss Locomotive and Machine Works at Winterthur built for experimental purposes a high-pressure locomotive with an average pressure of 700 lb. per sq. in. and a maximum boiler pressure of 850 lb. This boiler works in conjunction with a high-speed uniflow engine and reduction gearing. Among the advantages of the latter is the fact that the same standard engine can be used for different services, a change in the gear ratio being sufficient to convert a freight into a passenger locomotive. Production can thus be simplified and the number of spare parts reduced.

The present engine and boiler were tested on the testing bed before being put into the locomotive.

Owing to the moderate weight and dimensions of high-speed engines, it would be possible to generate 3000 effective horsepower on a single frame, and as much as 4000 to 5000 hp. may prove possible with the Garratt type. The crankshaft and gears are completely protected from dust, and they are thoroughly lubricated, so that wear and tear should be very much less than with the normal type of locomotive engine. With the gear drive, the designer has a wide choice in fixing the number of cylinders to be adopted. Three have been used for the Winterthur high-pressure engine, and the torque per revolution varies only 8 to 10 per cent from the mean, while with the normal type of four-cylinder locomotive the variation may be as much as 25 per cent. Uniformity of torque is favorable to adhesion, and a figure of 33.3 per cent has been recorded with the new engine with dry rails. Balancing is improved and the destructive effect on road-bed and bridges is correspondingly diminished.

Compounding was rejected, since to be satisfactory with such high initial pressures, intermediate superheating would be necessary, and a more complicated valve gear would be required. Both facts would run counter to the aim at simplicity, which has been a governing factor in the design of the new engine. It was, therefore, decided to adopt a three-cylinder uniflow engine, having cam-operated admission valves of the poppet type, which have special advantages where high superheats are used.

The engine has three double-acting cylinders and is designed to run at a speed up to 700 r.p.m. The camshaft operating the valves is above the cylinders. It runs on ball bearings and is coupled to the crankshaft by bevel gears. There are three cams to each cylinder and the cut-off is varied and the engine reversed by sliding the camshaft axially. In normal running an evaporation of 8000 lb. of steam per hr. at a pressure of from 740 to 850 lb. per sq. in. was easily maintained. The evaporative efficiency was 0.8 and 600 lb. of steam were generated per hr. per sq. ft. of grate area.

The road tests made over a considerable period of time indicated an average reduction of 35 to 40 per cent in fuel consumption and from 47 to 55 per cent of water supply was needed. (*Engineering*, vol. 126, no. 3261, July 13, 1928, pp. 51–53 and 4 pp. of illustrations, *dA*)

SPECIAL MACHINERY

Design of Pressure Vessels for the Petroleum Industry

IN THESE vessels is required the combination of ability to withstand certain mechanical pressures together with elevated temperatures. Oil-cracking operations can be carried out commercially at 900 deg. fahr. It has been found, however, that the long-time strength of metal at this temperature is much less than was expected. It is also said that it is becoming recognized that for the oil-cracking industry, plain carbon steels are preferable to ordinary alloy steels because the increase of strength with use in the latter at elevated temperatures is not sufficient to compensate for the higher cost of the steel itself and its fabrication. The advantages in the matter of corrosion resistance become apparent only when very expensive alloys are used which are usually high-chromium or chromium-nickel alloys, but some of the very high-chromium steels are said to become quite brittle at the high temperatures involved. High-alloy steels containing both chromium and nickel are said to be free of the defect of brittleness.

The strength of various steels at elevated operating temperatures is a matter in which short-time tests give very erroneous results when considered as a basis for determining long-time loading. The author illustrates this by giving results of tests on two steels at 900 deg. fahr. In these tests, the long-time loading is barely one-half of the short-time loading.

As regards corrosion it would appear that temperature has a considerable effect on the rate of corrosion and that for certain temperature ranges this corrosion rate at a given pressure and condition of stress in a vessel does not necessarily increase as the temperature increases.

The effect of the shape of various parts of vessels is a matter of great importance from the point of view of strength of the vessel. In vessels constructed by a method of welding and in which the joint is not made essentially thicker than the main cylinder and in which a joint efficiency of at least 100 per cent prevails, the question of shape of heads and reinforcing is the only one that need be considered. Fabrication strains may be eliminated by annealing and, for example, the A. O. Smith Corporation of Milwaukee, Wis., uses for this purpose an automatically controlled electric furnace 80 ft. long and able to accommodate vessels up to 12 ft. in diameter. Incidentally this is the largest furnace of this type in existence.

The author describes in detail the various tests made to determine the strength of the vessels. This, while of interest, cannot be abstracted because of lack of space. The need for reinforcing all openings in vessel walls has been demonstrated. The heads of thick-walled vessels in particular should conform to the best mathematical design for economical stress distribution. It is believed that heads for all pressure vessels should be elliptical in shape. An ordinary dished head reduces the strength of a vessel. The correct shape of head to develop the full strength of the cylinder of the vessel is one-half of an ellipsoid that has the major axis equal to the diameter of the vessel and the minor axis equal to one-half of this value. Minimum thickness of the head should be at least equal to the thickness of the cylinder. (T. McLean Jasper, Director of Research, A. O. Smith Corporation, paper before Western Refiners Association, presented on May 31, 1928, abstracted through *Power*, vol. 68, no. 4, July 24, 1928, pp. 164–167, *edA*)

Forging and Coining Press

THE design of this press was evolved from tests carried out by the firm L. Schuler A.G., at Goeppingen, Germany. These tests proved that the amount of work required for a given change of shape of apiece of metal always rises with the increasing ra-

pidity in the rate of deformation. This additional work is always greater for a given diameter of the piece, the lower the piece and the greater its strength. From this it would appear that slow deformation saves power. This led to the adoption of a toggle-type press, a machine which, while requiring a minimum of time for finishing the piece, works at a slow rate of deformation of the metal.

The toggle joint is provided with forced lubrication and operated by a crank. Pressures up to 2000 tons may be obtained and the pressure during the work is indicated by a special gage. The frame of the standard press is an iron casting reinforced by shrunk-in steel columns.

This press permits what is known as "coining" which means finishing by forming to exact limits of work previously rough-formed to approximate size. This operation is intended to take the place of finish-turning or milling. (Otto Kühner in *Engineering Progress*, vol. 9, no. 6, June, 1928, pp. 171–172, 4 figs. *d*)

German Strip Mills

THE PRESENT article deals with the general situation affecting strip rolling in Germany and describes in particular the practice of the Thyssen Company.

It would appear that the maximum width of strip that is commercially rolled in Germany is 400 mm. which corresponds to 16 in. in the United States with the weight of coils of a maximum of 400 kilograms (800 lb.). Mills are available, however, which could roll wider stuff had there been a sufficient demand. In this connection, the author mentions the practice of the Weirton Steel Company in America and states that the output of its 950 mm. by 1.6 mm. (say 16 gage) is about as large as the entire output of finishing sheet mills in the whole of Germany.

Apparently in the last years there has been a tremendous increase in demand for steel strip in Germany. Among other things there is a big demand for narrow strip to be used for packing (what would be called hoop in America). It is stated, for example, that one German mill sells on an average of 1775 tons of packing hoop in widths of 8 to 25 mm. (0.314 to 0.984 in.). It is also stated in this connection that the mill in question is working at the rate of only 50 to 60 per cent of its capacity.

As in America, customers are demanding compliance with increasingly strict specifications as to quality, finish, and tolerances. Before the War, about 90 per cent of the strip produced was rolled from basic Bessemer steel. Today, not more than 70 per cent is rolled of such steel and the other 30 per cent comes from open-hearth and special steels. As to tolerances, the following data are given: For solid rolled steel, the tolerances vary in respect to thickness from 0.1 to 0.25 mm., plus or minus, depending on width and thickness (0.0039 to 0.0098 in.). For widths up to 80 mm. (3.149 in.) the permissible variation in width is $\pm$ 1 mm. (0.039 in.), from 80 to 150 mm. $\pm$ 1.25 mm., from 150 to 300 mm. $\pm$ 1.5 mm., and from 300 to 400 mm. $\pm$ 2 mm.

In cold-rolled strip, the permissible variations in thickness are $^1/_{10}$ those allowed in hot-rolled strip. As regards width, the same tolerances are allowed as in hot-rolled strip and where greater tolerances are desired the strip is trimmed to size. Furthermore, in hot-rolled strip the material must not be rolled below the minimum permissible thickness. A very much closer tolerance as to thickness can be maintained in cold-rolled strip.

As a rule, strips up to 6 mm. in thickness (0.236 in.) are rolled with edges as arcs. The heavier strip can be supplied, but it is not guaranteed as to surface condition. Thinner strip may be delivered trimmed if desired. The narrowest untrimmed strip is of about 7 mm. (0.275 in.), while the widest strip that can be rolled in Germany goes to about 60 mm. (23.622 in.).

The first strip mill in Germany was built in 1871 by the Thyssen Company. Since then, the company has installed a number of other mills, gradually improving the practice and design, and the original article shows (Fig. 4) a "semi-continous," really a tandem, mill of the most modern design. This mill consists of a continuous rough-rolling mill and a finishing mill. The roughing mill consists of 8 duo mills of large section which is intended to produce a better surface of strip. As the stands in this continuous mill are placed at such a distance from each other that the material rolled is not in tension, the speed regulation appears to be comparatively simple. Billets of the most varied width and length are rolled. They start from a gas-heated furnace, having an output of 15 tons per hour and the time between their going into the furnace and their discharge to the rolls is on an average of 4 hr.

From the furnace, the billets go to the 8-stand rough-rolling mill and from there into the finishing rolls consisting of two double-duo stands with rolls running at the same speed. The first of the continuous stand is an edging stand which reduces the billet to a width of 70 mm. (2.755 in.). On coming from the edging stand the billet is turned over to an angle of 90 deg. and in this position goes into the second stand and then through the

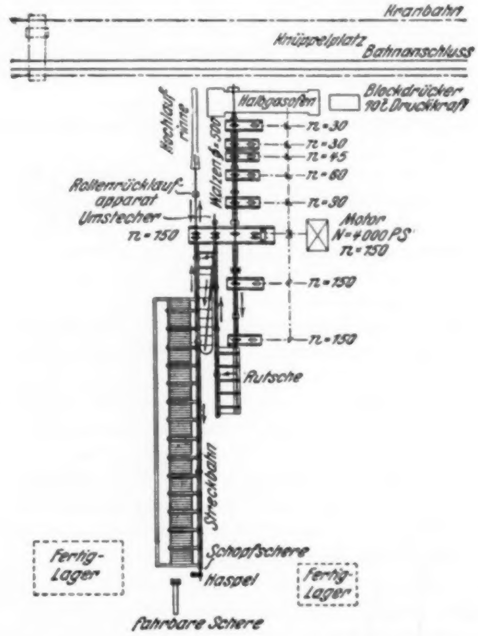


FIG. 4 SEMI-CONTINUOUS, THYSSEN STRIP MILL

next five duo stands with roller beds between. The seventh pass is a finish-edging pass, the purpose of which is to smooth off the edges of the strip and bring it to the required width.

A somewhat complicated mechanical arrangement is used to convey the strip from the rough-rolling to the finishing mills. A figure in the original article gives an interesting curve showing the power consumption in rolling a billet 280 $\times$ 75 $\times$ 1000 mm. (11.023 $\times$ 2.952 $\times$ 39.370 in.) into a strip 280 $\times$ 2.75 mm. (11.023 $\times$ 0.107 in.).

As in America the increase in the rate of wages and the introduction of an eight-hour instead of the previous ten-hour day led to a vigorous effort to reduce man-power, as a result of which a number of mechanical devices, particularly handling devices have been introduced. These do not apparently differ much from the American practice. (F. Winterhoff Dinslaken, Report no. 58, of the Rolling Mill Bureau of the Association of German Steel Manufacturers, abstracted through article in *Stahl und Eisen*, vol. 48, no. 27, July 5, 1928, pp. 897–903, 12 figs., *d*)

STEAM ENGINEERING

New Swedish Boiler

THIS boiler shown diagrammatically in Fig. 5 has been constructed according to designs of N. Forsselad, Technical Chief of the Electricity Works of Stockholm, Sweden. It may be adapted for oil firing or powdered-coal firing and is an internally fired single-drum sectional unit.

The combustion chamber is surrounded by six sections, each consisting of upper and lower headers connected by 4-in. straight tubes. The upper headers are connected to a horizontal cylindrical drum at the top of the boiler, while the lower headers are connected to a short vertical drum at the bottom. Between the upper and lower drums a 16-in. connector is arranged, which runs through the center of the furnace and is protected by firebrick. For high pressures, for which the construction seems to be particularly suited, this 16-in. connector may be replaced by a number of ordinary tubes.

Burners are fixed at the six lower corners of the furnace and produce a flame around the connector in the center, which acts as an ignition arch.

The gases, escaping at the upper ends of the sections, pass downward through two superheaters in parallel in the oil-fired unit or through a superheater at one side and an economizer at the other side in case of the second unit, thence upward through an air heater to the fans and chimney. The air heater is recuperative and is specially designed for high-temperature working. It is partly built up from sheets of stainless steel and heats the combustion air of the oil-fired boiler to a temperature of about 1100 deg. fahr.

It will be clear from the description that the furnace is entirely surrounded by heating surface, and that there is no additional heating surface outside the furnace. The unit is to be regarded as a recuperative steam furnace with economizers arranged between the furnace and the recuperator. It would, however, be easy to put in some additional heating surface if it were required.

The actual heating surface of the steam-raising tubes of the oil-fired boiler is 2350 ft. sq. and the evaporation from cold water to steam of 280 lb. pressure and 800 deg. fahr. is 88,000 lb. per hr. or 37.5 lb. per sq. ft. The boiler is capable of raising steam very rapidly, and full pressure can easily be obtained from the cold state in 11 to 12 min.

The evaporation of the second boiler is not exactly known. It is, however, estimated to be at least 100,000 lb. from cold water. The heating surface of that boiler is 2400 sq. ft.

The pulverized coal mills are arranged for direct firing and for drying the coal by means of hot air from the air heater belonging to the boiler. The design once again calls attention to the fact that large furnace volumes are not so essential to good boiler efficiency as so many assume. By reason of the small furnace the heating surface per cubic foot of room volume is higher than is customary. When pulverized coal is used the shape of the furnace is such that gravity assists in holding the particles in the furnace until consumed.

Contrary to what might be expected the central pipe does not absorb heat to the extent where its downward circulation is interfered with.

The advantage claimed for the boiler is high overload capacity and low first cost, the latter being, it is said, only one half compared on the basis of evaporation with the water-tube boilers previously used in the station. (N. Farsselad, *Power*, vol. 67, no. 24, June 12, 1928, pp. 1054–1055, 2 figs., *d*)

TESTING AND MEASUREMENTS

X-Ray Inspection of Metal Articles

THE author describes methods of X-ray inspection of small castings. He states that the cost of X-ray installations ranges from $1000 to $8000. For practical inspection work with

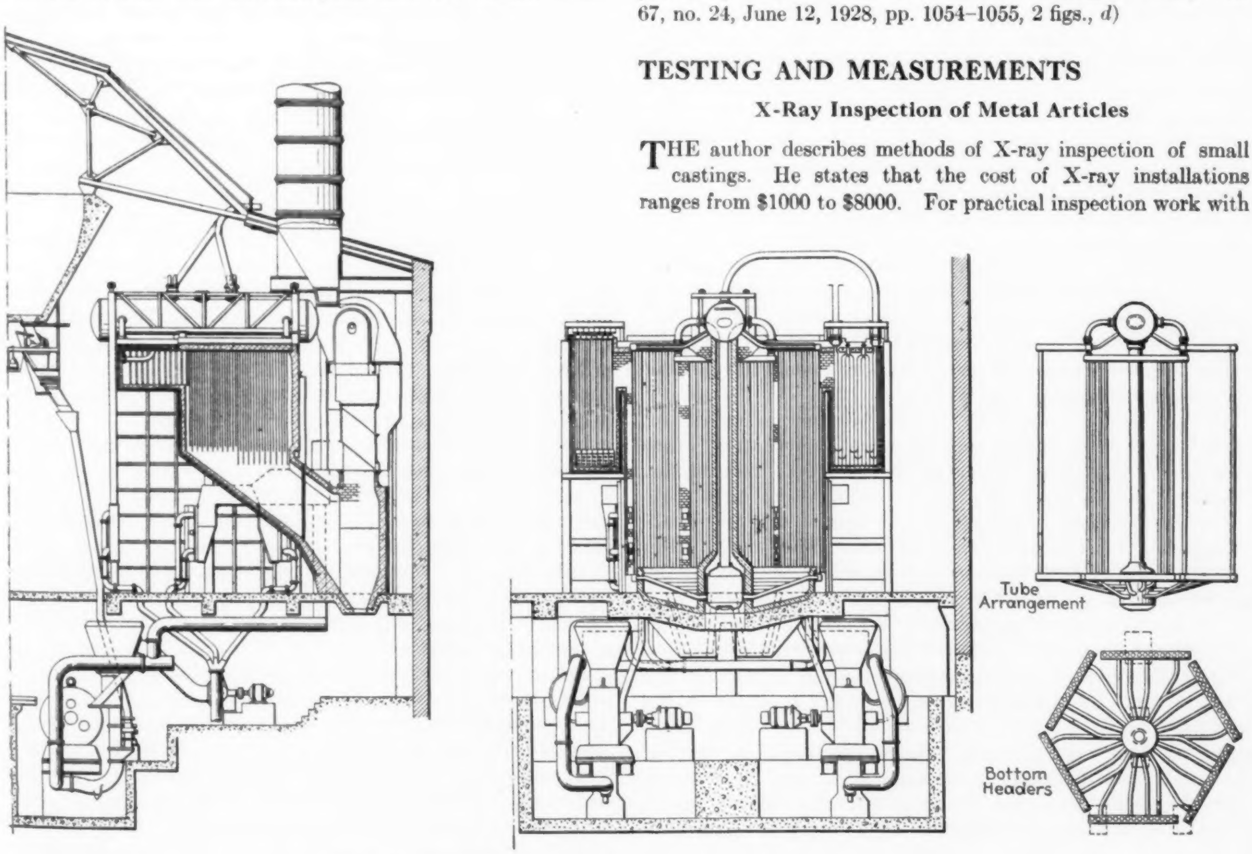


FIG. 5 THE SWEDISH BOILER ARRANGED FOR PULVERIZED COAL

a fluorescent screen, a special outfit is available wherein the castings pass on a conveyor belt right through the X-ray field. One checker can inspect the entire output as only a few seconds are necessary for each piece.

In practical routine examination, good details are obtained in X-ray inspection of bronze up to 2 in. thick, iron up to $3^1/_2$ in., and aluminum up to 12 in. For inspection on the fluorescent screen the thicknesses are for bronze, about $^1/_2$ in., for iron 1 in., and for aluminum 4 in. Straight smooth shapes are more suitable for inspection than complicated ones with different thicknesses and the latter require more skilled technique. The author gives illustrations of defects which may be discovered by X-ray inspection as follows:

1 Examination of cast blocks and bars before rolling or drawing to determine impurities and porosity
2 Examining pipes or cables for shrinkage or cracks for over drawing
3 Inspection of high-pressure machine parts (cylinders, pistons, boiler plates and the like) before fitting in, or inspecting expensive steel castings before machining
4 Control of welded or soldered seams
5 Fluoroscopic inspection of die castings
6 To ascertain changes within heavy-duty materials like propellers made of wood or aluminum.

(Herbert R. Isenburger in *The Metal Industry* (New York), vol. 26, no. 6, June, 1928, pp. 271–272, 5 figs.)

A Precision Value for the Inch

AFTER a brief discussion of the primary standards at the United States Bureau of Standards, the author puts forward a claim that the inch as the controlling unit of measurement should be made precise.

The primary standards of length of the Bureau of Standards are not prepared as such but are derived in a roundabout way from metric standards. In the Act of Congress of 1866, the meter was defined as 39.37 inches which established an American meter in terms of inches many years before the organization of the International Bureau of Weights and Measures at Sèvres in 1875. In 1927 representatives of the Nations assembled at the Seventh International Conference on Weights and Measures agreed to accept the length of the international meter as 1,553,164.13 wave lengths of the red ray of cadmium. A wave length of the red ray of cadmium is about a quarter of a ten-thousandth of an inch. British authorities operate on an Order of Council, May, 1898, by which the yard was defined as 0.914399 meter and this value of the yard has been used since that time.

In the United States the status of the international meter with its relation to the yard rests entirely on an "authorization" of the Secretary of the Treasury promulgated in 1893. This relation has never been legalized by Congress and the Constitution provides that Congress alone shall "fix the weights and measures." This has led to some confusion and the author shows that based on final relations, one United States inch equals 25.40005 mm. while one British inch equals 25.39998 mm.

It is, however, only when considered in reference to and in terms of the International Meter, as above explained, that there is any difference between the length standards of Great Britain and the United States. In fact those manufacturers of the two countries who have daily dealings in length standards, even in precision standards used in tool and gage manufacture, refuse to recognize that there is any difference in the standards of the two countries. Nevertheless the fiction that there is a difference has spread widely, and is incorporated today in the scientific and engineering literature of the world. It is moreover accepted in Germany and France, where a great deal of manufacture in the inch is carried on today. Hence it is important to have this fiction eradicated as soon as possible.

As matters stand today, however, the inch, which is probably the most important unit of measurement in the world, has no legal definition.

The acceptance of the determination of the light-wave value of the meter points the way to the practicability of also determining the yard, the foot, and the inch in terms of red rays of cadmium and in a specified relation to the meter. As has been shown, the scientists in Great Britain define the inch as 25.39998 mm. while those in this country define it is 25.40005 mm. The mean of these two values is approximately 25.4 mm., and as a matter of fact this is the value which is always used in manufacturing, where inches need to be converted readily to millimeters and where an error in the fifth decimal place is not material.

For the mechanical conversion of inches to millimeters a conversion factor with a small number of figures is not practicable. The figure of 25.4 has this advantage as it allows the use of a gear ratio of 5 to 127, so that if a screw-cutting lathe, for example, is built to inch dimensions and has its lead screw cut to inches, a gear ratio obtained by using a 127-tooth gear in the train will give a feed in millimeters; and in the same way any machine having its lead screw in millimeters can be used to produce screws or other parts dimensioned in inches.

If, by about equal concessions on the part of Great Britain and of the United States, duly authorized by law in the two countries, the inch could be agreed upon as 25.4 millimeters, the manufacurers of these countries would probably be willing to accept this as the basis of the inch.

The author shows how by accepting the value of the international meter as 1,553,164.13 of the red rays of cadmium, and accepting the conversion factor of the inch as 25.4 mm. the value of the inch in terms of wave lengths would be 39,450.368902. When it comes to the question of how many significant figures are necessary, the author points out that the decimal 0.368802 is very near to $^1/_3$. This would give an expression for the inch as $39{,}450^1/_3$, which in turn would give the number of waves in a yard as 1,420,-212, an even number.

The Bureau of Standards has already suggested that the yard be defined as 1,420,213.28 wave lengths.

It would thus seem advisable to recommend that the United States, Great Britain, Canada, and the other British Commonwealths, accept the value of International Meter of 1,553,164.13 wave lengths, and then agree on the conversion factor of 1 inch equals 25.4 mm. for practical use, and further agree on establishing the wave-length value of the inch as $39{,}540^1/_3$ waves as fundamental. It is seen that this will act to give the inch its precise value and relative status which all desire so urgently.

In the United States the acceptance of such a proposal would probably remove much of the opposition to the Order, approved by the Secretary of the Treasury in 1893, which is claimed to have given the metric standards an authority which Congress has never intended them to have.

This would not only pave the way for accord between Britain and America, but would also bring scientists and manufacturers and the Government departments in the United States itself to a better mutual understanding.

The acceptance of this proposal should be followed by the making of physical standards for the foot, yard, etc., having at least the same degree of refinement as the present metric standards. These could then be used as fundamental without conversion from metric when comparing industrial standards, and also as a basis for whatever precision work on length standards is done from now on. (Luther D. Burlingame, Brown & Sharpe Mfg. Co., Providence, R. I., Scientific Paper, *American Institute of Weights and Measures*, June, 1928, pp. 3–9, *g*)

Engineering and Industrial Standardization

National Safety Regulations for Construction Industries to Be Developed

AS THE result of a conference held June 29 in New York, among government officials, safety experts, contractors, and engineers, a set of safety regulations for construction work is to be developed by a Sectional Committee organized under the auspices and procedure of the American Engineering Standards Committee which has established national safety codes for several other industries. The conference was held at the request of the Association of Governmental Labor Officials of the United States and Canada which feels that the establishment and acceptance of national safety rules will go a long way toward cutting down the great loss of life in the construction industries.

The seriousness of the situation is revealed by figures made public by the New York State Department of Labor, showing that over 1000 workmen are killed in the construction industries each year in New York State alone, and 20,000 more are injured in the State. Safety men estimate that there are ten times as many accidents in construction in the entire nation. One-quarter of all industrial fatalities in the State, the Department points out, are in construction.

These figures were further amplified at the conference by Mr. L. L. Hall of the National Council on Compensation Insurance, who gave a comprehensive picture of the situation by summing up the losses for the thirty-two states which have compensation laws, basing his estimate on the New York law of January 1, 1927, since the compensation laws of the various states varied considerably. During the five-year period, 1920–1924, there were in the contracting industry, exclusive of erection, 3868 serious accidents, a total of 92,553 accidents, with losses in compensation, time, medical attendance, etc., amounting to \$48,712,056; while in erection work during that period there were 7142 serious accidents, a total of 1,824,901 accidents, with losses amounting to \$102,602,709.

Some of the chief causes of the serious accident hazards in construction, according to the Association of Labor Officials, are to be found in the nature of the industry where apparatus and equipment are necessarily portable and labor is constantly shifting. While part of the accidents are believed to be unavoidable, it is felt that the establishment of national safety rules would materially decrease the number of accidents.

Speaking for the Associated General Contractors of America, Mr. C. S. Embrey stated that his association wished to go on record as endorsing the assertion of Dr. A. F. McBride, Commissioner of Labor of New Jersey, that something must be done, but that they differed radically in regard to the measures to be adopted. The number of accidents had of late shown a marked increase, but the fact that the volume of work done had also tremendously increased had been almost overlooked. His association was of the opinion that the proportion of accidents to the volume of construction had not increased. The formulation of safety codes presented no great difficulty for industries of a permanent character, but the proposition was an entirely different one for the construction industries with their mobile plants. After eighteen months' intensive study, twelve months of which had been spent in active educational work, the A.G.C. had come to the conclusion that the situation could be controlled by educational means alone. As the only organization big enough to make its mark in such educational work, they had collected a fund for the purpose, and twenty-six cities had been visited to inaugurate safety work within the A.G.C. and in affiliation with that organization. Simple directions had been compiled in a "Manual" and widely distributed. A school of accident prevention already existed in Los Angeles, and others were being formed in Milwaukee, Detroit, and Philadelphia. Mr. Embrey said that he was instructed to state that the A.G.C. must withhold approval of any "paper codes," as such measures would only tend to discourage educational methods, which they were convinced were the proper means to control the situation.

After a thorough discussion of the subject during which many letters of approval from state officials were read, it was the consensus of opinion of the conference that the project should go forward and the more serious hazards dealt with first. It therefore recommended to the A.E.S.C. that the present scope of the proposed code or codes be confined to the construction, demolition, and repair of buildings; including excavation, foundation work, steel erection, scaffolding, lighting, openings, temporary floors and stairs, in relation to accident hazards to employees and to the public.

The Conference recommended that the Associated General Contractors of America and the Association of Governmental Labor Officials of the United States and Canada be requested to accept joint sponsorship for the project and that a large number of interested organizations be invited to appoint representatives to the sectional committee organized to undertake the formulation of the Code.

New Proposals for American Standards by Member Bodies of A.E.S.C.

DURING the past month the American Engineering Standards Committee has been requested by several of its member bodies to authorize the organization (under its procedure) of a number of new standardization projects.

The National Electrical Manufacturers Association proposes the standardization of "Panelboards and Distribution Boards"

NEW A.E.S.C. STANDARDS

The following standards were approved by the A.E.S.C. during the month of July 15–August 15, 1928:

Storage Batteries. (American Standard.)

Sponsored by the American Institute of Electrical Engineers. Published by A.I.E.E.

Railway Motors. (American Standard.)

Sponsored by the American Institute of Electrical Engineers. Published by A.I.E.E.

Outside Coal-Handling Equipment. (Tentative American Standard.)

Sponsored by the American Mining Congress. Published by A.M.C.

for the purposes of economy and safety and to facilitate their proper selection for various applications. The scope of the proposed project includes definition, types, their selection, application, design, construction, performance, and test.

Another project in the electrical field has been proposed by the American Institute of Electrical Engineers under the title of "Electrical Definitions." The scope of this standardization project, as visualized by the Institute's Standards Committee, would be chiefly the coordination of existing definitions developed by the organizations engaged in standardization work in the electrical field.

Six projects have been proposed by The American Society of Mechanical Engineers. They include standardization of (*a*) pressure and vacuum gages, (*b*) stock sizes and shapes for flat and round iron and steel bars, (*c*) leather belting, (*d*) splined shafts and splines, (*e*) screw-stud dimensions, and (*f*) rolled threads for screw shells of electric sockets and lamp bases.

During the years 1912–1914, a committee of the A.S.M.E. developed dimensions for rolled threads for screw shells of electric sockets and lamp bases, and their gages. The committee's report covered miniature, candelabra, medium (Edison), and Mogul sizes. Since then the manufacturers have found it necessary to add a fifth size now known as the "intermediate" size. This thread is smaller than the medium size and larger than the candelabra. It has been suggested, therefore, that this is an opportune time to revise and present to the A.E.S.C. for its approval the present American practice in the manufacture of these threads.

A.E.S.C. to Change Its Name and Constitution

THE reorganization of the American Engineering Standards Committee is intended to permit it to keep pace with the growth of the industrial standardization movement in the United States. The principal features of this reorganization are (*a*) the definite federation of national organizations, under the name "American Standards Association," in such a way that trade associations interested in standardization may more readily join in the direction of the movement placing the technical work of approving standards in a "Standards Council," and (*b*) the concentration of the administrative and financial responsibility in a "Board of Directors" composed of twelve industrial executives.

The reorganization has been unanimously approved by the Main Committee of the A.E.S.C., and is now being voted upon by the member-bodies. The action of the Committee results from more than a year's intensive consideration of the subject by the Main Committee and Rules Committee. The latter was enlarged for the purpose to include a representative of each of the nineteen member-bodies desiring representation.

In submitting the plan for the formal approval of the member-bodies, William J. Serrill, Chairman of the A.E.S.C. Main Committee states:

"The ten years' experience of the Committee has brought to light certain fundamental difficulties inherent in the old organization. It is the purpose of the reorganization to eliminate these difficulties, to place the operation of the Committee on a sound administrative basis, and to facilitate the financing of the work on an adequate scale."

Among the conditions which led to the reorganization are the growth of the trade-association movement together with the predominating position which the trade association is coming to have in the field of industrial standardization, and the increasingly important direct part which the plant executive is playing in the standardization activities within this plant and in the movement as a whole. Recognition of this latter condition is reflected in the make-up of the "Board of Directors," which will control the general administrative and financial affairs of the association. The industrial executives composing this board will be elected on nomination of member-bodies, and will serve for three years.

Approval both of standards and matters of procedure will be in the hands of a "Standards Council." The council will be composed of not more than three representatives of each of the member-bodies, the councilors also serving for a period of three years.

The underlying principles of the A.E.S.C. remain unchanged. The basic functions remain completely in the hands of the representatives of the member-bodies. The individual members, whether of the Board of Directors or of the Standards Council, are appointed or nominated by the member-bodies, which thus remain the fundamental units in the organization.

The name American Standards Association is being adopted as more accurately descriptive of the reorganized association, and also because of the misunderstandings and misconceptions which have frequently occurred in connection with the words "engineering" and "committee." The scope of the work is, however, being limited to those fields in which engineering methods apply.

The objects of the Association, as stated in the new constitution will be: to provide systematic means by which organizations engaged in industrial standardization work may cooperate in establishing American standards in those fields in which engineering methods apply, thus avoiding duplication of work and the promulgation of conflicting standards; to serve as a clearing house for information on standardization work in the United States and foreign countries; to further the industrial standardization movement as a means of advancing the national economy, and to promote a knowledge of, and the use of, approved American industrial and engineering standards, both in the United States and in foreign countries; and to act as the authoritative channel in international cooperation in standardization work, except in those fields adequately provided for by existing international organizations.

The revised procedure of the committee, which forms a part of the general reorganization, and in which there is much more flexibility than formerly, is already in effect. Under the new procedure, a sectional committee may operate autonomously, reporting directly to the A.E.S.C., or it may act under a sponsor as heretofore. "Proprietary" standards are recognized and may be revised within a single organization on condition that it be shown that the standard is acceptable to the groups concerned—a method particularly applicable to highly specialized fields. In very simple cases, approval is based upon the action of a conference followed by written acceptances of the interested groups. (See article entitled "A.E.S.C. Changes Procedure," Mechanical Engineering, June, 1928, page 484.)

The proposed revision of the constitution follows.

Proposed Revision of Constitution

ARTICLE I

Name

Section C 1. The name of this organization shall be the American Standards Association (A.S.A.).

ARTICLE II

Objects

The bodies associating themselves in accordance with this Constitution do so with the following objects:

Section C 2. To provide systematic means by which organizations concerned with standardization work may cooperate in establishing American Standards in those fields in which engineering methods apply, to the end that duplication of work and the promulgation of conflicting standards may be avoided.

Section C 3. To serve as a clearing house for information on standardization work in the United States and foreign countries.

Section C 4. To further the standardization movement as a means of advancing national economy, and to promote a knowledge of, and the use of, approved American industrial and engineering standards, both in the United States and in foreign countries, but not to formulate standards.

Section C 5. To act as the authoritative American channel in international cooperation in standardization work, except in those fields adequately provided for by existing international organizations.

ARTICLE III

Membership

Section C 6. There shall be five classes of members: Member-Bodies, Honorary Members, Directors, Councilors, and Sustaining-Members, as defined in sections C 7, C 8, C 9, C 10 and C 11.

Section C 7. Member-Bodies shall be organizations or groups of organizations of national scope, with which the ultimate general authority and responsibility for the policies and affairs of the Association shall lie.

Section C 8. Honorary Members may be elected as provided in the By-Laws.

Section C 9. Directors shall be members of the Board of Directors, as hereinafter provided.

Section C 10. Councilors shall be members of the Standards Council, as hereinafter provided, upon which they shall be the representatives of the Member-Bodies appointing them.

Section C 11. Sustaining-Members shall be organizations, companies, or individuals interested in the work of the Association and subscribing to its support, as provided in the By-Laws.

Section C 12. Organizations or groups of organizations may be admitted as Member-Bodies by action of the Board of Directors, for which action a three-fourths vote of those present and voting shall be required.

Section C 13. Each Member-Body shall pay annual dues as fixed in the By-Laws.

Section C 14. Any Member-Body may terminate its membership upon notice in writing, provided its dues, including those for the current calendar half year have been paid.

ARTICLE IV

Officers

Section C 15. There shall be a President and a Vice-President, who shall perform the duties usual to these offices. They shall be elected by the Board of Directors, and not necessarily from the membership of the Board. They shall serve for one year, or until their successors are elected. They shall not serve in these respective offices for more than three consecutive terms.

Section C 16. A Secretary, or other executive officers of the Association, who shall not be members either of the Board or of the Standards Council, shall be appointed by the Board of Directors.

ARTICLE V

Board of Directors

Section C 17. The executive, financial and general administrative functions of the Association, but not the function of approving standards, shall be vested in a Board of Directors consisting of the President, the Vice-President, the Junior Past President, and nine elected Directors.

Section C 18. The elected Directors shall serve for a term of three years, or until their successors are elected. They shall be elected by the Board upon nominations by selected Member-Bodies, as provided in the By-Laws.

ARTICLE VI

Standards Council

Section C 19. There shall be a Standards Council composed of not more than three representatives from each Member-Body, and *ex officio*, of the President, Vice-President, and the Junior Past President of the Association, and the two Junior Past Chairmen of the Council. Members of the Council shall be termed Councilors. They shall serve a term of three years, and they shall be eligible for reappointment. Member-Bodies may appoint regular alternates to their Councilors to act for them in case of absence or disability of the latter.

Section C 20. The functions of the Council shall be to formulate rules for the development of standards and for the constitution of committees; to approve, on behalf of the Association, such standards as it may find to be supported by a consensus, affirmatively expressed, of those substantially concerned with the standard; but not to formulate standards.

ARTICLE VII

By-laws

Section C 21. By-Laws shall be adopted not in conflict with this Constitution.

Section C 22. Amendments to the By-laws fixing amounts of dues of Member-Bodies, and their method of payment, shall be pursuant to the methods provided for effecting amendments to this Constitution.

Section C 23. The By-Laws proposed by the American Engineering Standards Committee in order to bring its administrative routine into conformity with this Constitution, and identified by the symbol MC 680, 1928, shall automatically become the By-Laws of the Association until amended in accordance with Section 81 thereof.

ARTICLE VIII

Amendments

Section C 24. Amendments to this Constitution must be proposed in writing at least thirty days before the meeting of the Board of Directors at which they are to be voted upon, this vote to be upon the amendment as originally proposed or as further amended at the meeting. If approved by three-fourths of those present they shall be referred to the Member-Bodies and shall become operative only when they have been approved by three-fourths of the Member-Bodies.

ARTICLE IX

Transition Measures

Upon formal ratification of this revised Constitution by three-fourths of the Member-Bodies.

Section C 25. The Chairman and Vice-Chairman of the American Engineering Standards Committee shall assume the titles of President and Vice-President, respectively, of the American Standards Association, during the remainder of their terms; and the Main Committee shall become "The Standards Council."

Section C 26. Until such time as the first Board of Directors is organized, general administrative and financial matters shall continue in the hands of the Executive Committee as organized under the American Engineering Standards Committee.

Section C 27. There shall be constituted an interim Organizing Committee, consisting of the President, the Vice-President, the two Junior Past Chairmen of the American Engineering Standards Committee and the Director of the Bureau of Standards, whose duty shall be to organize the first Board of Directors, and to provide for such other transition matters as are not clearly functions of the officers or of any other agencies of the organization.

Section C 28. The organizing Committee shall select nine Member-Bodies from each of which they shall request the appointment of a Director. The nine so appointed, together with the President, the Vice-President, and the Junior Past Chairman of the American Engineering Standards Committee, shall constitute the Board of Directors for the remainder of the current calendar year.

Section C 29. The Organizing Committee shall provide for the determination, by lot or otherwise, of the terms of these nine Directors, three of which terms shall expire annually.

Section C 30. This Article shall cease to be a part of this Constitution when the Board of Directors is called to order at its first meeting.

The Conference Table

THIS Department is intended to afford individual members of the Society an opportunity to exchange experience and information with other members. It is to be understood, however, that questions which should properly be referred to a consulting engineer will not be handled in this department.

Inquiries will be welcomed at Society headquarters, where they will be referred to representatives of the various Professional Divisions of the Society for consideration. Replies are solicited from all members having experience with the questions indicated. Replies should be as brief as possible. Among those who have consented to assist in this work are the following:

ARCHIBALD BLACK, Aeronautic Division
A. L. KIMBALL, JR., Applied Mechanics Division
H. W. BROOKS, Fuels Division
R. L. DAUGHERTY, Hydraulic Division
WM. W. MACON, Iron and Steel Division
JAMES A. HALL, Machine-Shop Practice Division
CHARLES W. BEESE, Management Division
G. E. HAGEMANN, Materials Handling Division
J. L. WALSH, National Defense Division
L. H. MORRISON, Oil and Gas Power Division
W. R. ECKERT, Petroleum Division
F. M. GIBSON and W. M. KEENAN, Power Division
WINFIELD S. HUSON, Printing Industries Division
MARION B. RICHARDSON, Railroad Division
JAMES W. COX, JR., Textile Division
WM. BRAID WHITE, Wood Industries Division

Aeronautics

Design of Airship-Hangar-Door Trucks

A-1 Where may one obtain information on the design of airship-hangar-door trucks? These will be required to support loads of approximately 45 to 50 tons per wheel.

The Bureau of Yards and Docks, U. S. Navy Department, has had considerable experience in the design of such wheel trucks, especially in the construction of the large dirigible hangar at the Naval Air Station, Lakehurst, N. J. There have been very few hangars built of a size comparable with the Lakehurst hangar. It is believed that the Royal Air Force of Great Britain and this country are doing more at the present time on the construction of large hangars than any other country. It may be advantageous to communicate with the Royal Air Force. (P. L. Reed, Acting Chief, Bureau of Yards and Docks, U. S. Navy Department, Washington, D. C.)

Applied Mechanics

Acceleration of Water Flow Through an Orifice[1]

AM-7 If a vessel of considerable area filled with water has a very small orifice at a depth H below the surface of the water and this small orifice is opened in zero time, what time will be required for the velocity of the water issuing from the orifice to equal $\sqrt{2gH}$?

After normal flow through a small orifice has been established, the maximum velocity of $\sqrt{2gH}$ occurs not at the orifice itself, but at the vena contracta, which is distant approximately 0.5 the diameter of the orifice from the orifice. At the orifice itself, the mean effective component of the velocity is only 0.6 that at the vena contracta, while at a point in the rear of the orifice and distant from it only twice the diameter of the orifice, the velocity of the water would be of the general order of magnitude of $0.02\sqrt{2gH}$. According to Bernouilli's theorem, which holds for any individual stream line, the pressure drop due to the establishment of flow (neglecting friction) would be given at any point by $v^2/2g$. At the point last mentioned, the pressure drop would be only 0.0004 H; a negligible amount. Under steady-flow conditions, the total kinetic energy present in the reservoir back of the plane of the orifice is but little greater than that present in the short section of the stream between the orifice and the vena contracta. In other words, the effect of opening a small orifice is limited virtually to the very small volume of water immediately back of the orifice.

If the orifice be instantly opened, the first result would be the initiation of a pressure wave, or rather a wave of rarefaction, starting from the orifice and traveling with the speed of sound waves in water (4700 ft. per sec.), but rapidly becoming fainter as it spreads through the volume of the reservoir. It is not necessary to wait for this wave to travel the length of the reservoir. It will have produced its full effect upon initial velocity by the time it has traveled a distance equal to a few times the diameter of the orifice.

This wave operates to convert into velocity energy only the resilient energy already present in the liquid due to its compression. The internal energy made available in inch-pounds per cubic inch of liquid will be $(S_0^2 - S_1^2)/2E$ where S_0 is the pressure in the liquid at any point before opening the orifice, S_1 the subsequent pressure, and E the volume modulus of elasticity of the water. The kinetic energy necessary to establish steady-flow conditions at this same point, by Bernouilli's theorem, will be $(S_0 - S_1)$ in-lb. per cu. in. E is approximately 294,000 lb. per sq. in. and consequently unless the initial pressures at the orifice are extremely great, the kinetic energy made available by this initial high-speed wave will be negligible.

The remainder of the energy necessary to establish steady-flow conditions must come from the potential energy of pressure or elevation in the water, the difference between the potential energy available for the first few pounds of water, passing through the orifice, and the kinetic energy actually carried away by that water being available to furnish this kinetic energy. The relation may be expressed mathematically as:

$$\int\left(Hdm - \frac{v^2}{2g}\,dm\right) = K\frac{v^2}{2g}$$

in which H is the static head in feet acting on the orifice, v the velocity present in the water as it leaves the orifice, and K a constant depending upon the flow conditions back of the orifice. The expression $Kv^2/2g$ measures the total kinetic energy present in the water back of the orifice at any instant. It is equivalent to the energy present in a small prism of water flowing with velocity v, the prism having a cross-section equal to the area of the orifice and a length somewhere between 0.2 and 0.5 the diameter of the orifice, depending upon the degree to which uniform-flow conditions have been established and upon the assumptions as to the character of flow. The integration of this

[1] This subject has been discussed in a previous issue.

equation would develop an exponential curve, indicating, as has already been noted in this discussion, that an infinite time would be required to establish perfect uniform flow.

These conditions may be better visualized by use of a numerical illustration. Assume an orifice one square inch in cross-section under 25-ft. head. The theoretical velocity of efflux, steady-flow conditions, would be 40 ft. per sec. The resilient energy in the water is $\dfrac{(25 \times 0.434)^2}{2 \times 294{,}000} = 0.000201$ in-lb. per cu. in. or 0.000465 ft-lb. per lb. The actual velocity produced by it at the orifice would be 0.17 ft. per sec. This is nominal in comparison to the 25 ft-lb. per lb. necessary to cause the velocity of 40 ft. per sec., and indicates that the initial pressure or rarefaction wave through the water may be neglected so far as it concerns its effect on the velocity of the water.

Without attempting to develop exact values, an approximate idea of the rate of increase of velocity due to the gradual storage of kinetic energy in the water may be easily obtained. Using a mean value for the length of the imaginary prism of water already mentioned, K becomes 0.1. Replacing dm by the finite value 0.02 lb., we have

$$0.02\left[25 - {}^1/_2\left(\frac{v^2}{2g} + 0.000465\right)\right] = 0.1\,\frac{v^2}{2g}$$

$$0.5 = 0.11\,\frac{v^2}{2g} \quad \text{or} \quad \frac{v^2}{2g} = 4.55 \text{ ft.}$$

$$\text{and } v = 17.1 \text{ ft. per sec.}$$

After 0.02 lb. of water have flowed through the orifice, the velocity will have reached approximately 17 ft. per sec.

$$0.02\left[25 - {}^1/_2\left(\frac{v^2}{2g} + 4.55\right)\right] = 0.1\left[\frac{v^2}{2g} - 4.55\right]$$

whence $\dfrac{v^2}{2g} = 8.2$ ft. and $v = 23$ ft. per sec.

Flow of a second 0.02 lb. will be sufficient to allow an increase in velocity to 23 ft. per sec. Successive increments of the same amount carry the velocity successively to 26.8 ft. per sec. and 29.6 ft. per sec., etc. Time intervals will be roughly one-thirty-thousandth of a second to obtain the full benefit of the initial pressure wave, and then 0.0053 sec., 0.0023 sec., 0.0018 sec., and 0.0016 sec. for the flow through the orifice of the successive increments of 0.02 lb. of water each. That is to say, after the lapse of 0.11 sec., the velocity will have reached 29.6 ft. per sec., or three-quarters of its final value.

A second effect of the passage of the pressure wave through the water should be mentioned. The increase in velocity subsequent to the initial rise hinges upon the assumption that the water in the tank is flowing toward the orifice so as to replace that which passes out, and so maintain full pressure back of the orifice. This is not true during the interim period while the pressure wave is traveling to and being reflected back from the nearest free surface. During this period, the pressure back of the orifice will drop below equilibrium values in its effort to maintain and accelerate flow, and will then surge upward again as the wave returns and is re-reflected. The wave may conceivably make several trips before it is damped out. Consequently, instead of increasing steadily, as assumed, the velocity through the orifice may increase in several surges, in tune with the passage of the wave. In the particular case assumed, a round trip of the pressure wave takes 0.010 sec., and the pressure-wave effect can be treated as causing minor fluctuations superimposed upon the gradual increase in velocity already computed. With the free surface at a greater distance from the orifice, the time interval becomes greater and the magnitude of each surge also increases, so that the surges may gain a dominating effect in the computation.

I have not attempted to make more than a roughly approximate analysis, but these figures may give an idea of the sequence of events and of the general magnitudes involved. (M. F. Sayre, Associate Professor of Applied Mechanics, Union College, Schenectady, N. Y.)

Fuels

Fluttering of Oil-Burner Flame[2]

F-12 The flame of a domestic oil burner at certain times flutters violently, setting up a great rattling of the doors and breeching of the furnace. Can any member of the Society suggest possible causes of this action and methods of overcoming it?

It is the opinion of the writer that the answer to this problem is one of combustion instead of draft, as suggested by Mr. Groff's comments in the September, 1927, issue. With insufficient forced draft (mixture too rich), oil burns with a steady, smoky flame. With the correct amount of forced draft (proper mixture) and insufficient chimney draft (perhaps, but not necessarily, caused by restricted passages), the flame will burn steadily without smoke but the products of combustion will be driven out through the firing and clean-out doors by the pressure of the forced draft.

With high excess air, flame temperatures will be low with consequent tendency to flicker. This flickering may or may not be accompanied by smoke, depending upon the size of the combustion chamber and the rate of fuel feed. Flickering is produced by instantaneous changes in rate of combustion and, therefore, operates on a cumulative cycle, because the dying-out of the flame causes an accumulation of oil vapor in the furnace; this excess vapor quickly produces a more perfect mixture and a miniature explosion, or brightening of the flame follows. This builds up an over-fire pressure which retards the forced draft but, at the same time, accelerates the gases up the chimney. The flame burns properly for an instant, flame temperature is high, flue-gas temperature is normal, and the chimney is, therefore, more effective. The large quantity of gases produced by the explosion is quickly removed by the better chimney action, but the inertia of the gases moving rapidly up the stack lowers the over-fire pressure below its original value when flickering was first started, and an even worse condition is set up.

The limiting value of the change in pressure due to flickering is probably determined by the height of the chimney, which influences the inertia of the moving column of gases, and the frictional draft losses, which act as a damping device opposing the change in velocity.

This alternate raising and lowering of the furnace pressure sets up the clattering of the doors.

The condition can probably be overcome either by better correlation of fuel and air, or by installing some refractory lining in the boiler to produce higher temperature. (W. S. Garrett, Mechanical Inspector, N. & W. Ry. Co., Roanoke, Va.)

Questions to Which Answers Are Solicited

Boiler Corrosion

P-1 On boilers without economizers fed through feedwater heaters operating at 210 deg. fahr., or thereabouts, has there ever been evidence of corrosion due to lack of deaeration? If so, under what conditions and circumstances?

[2] This subject has been discussed in a previous issue.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies in Research and Standardization.

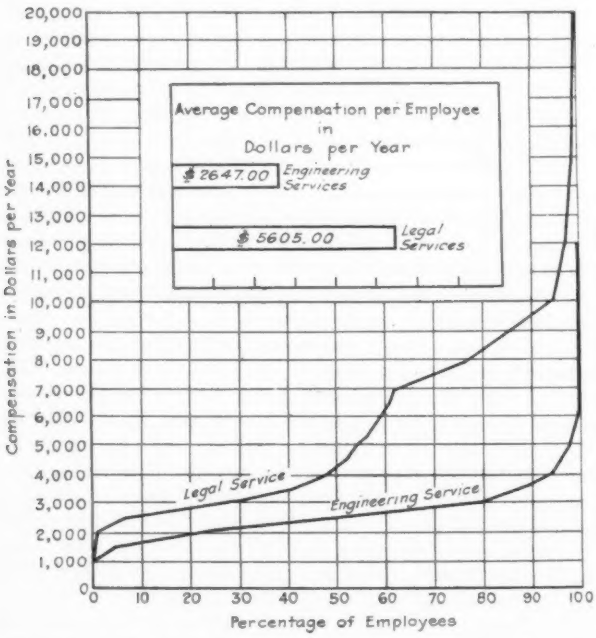
Wages of Engineers

To the Editor:

Mr. Crosby Field in the July issue of Mechanical Engineering takes exception to comparisons made between the engineering, the legal, and the medical professions.

He believes the point is often lost that the doctor is a business man whereas the engineer is in the vast majority of cases an employee.

The hypothesis is correct, but the conclusion is wrong.



Comparison of Salaries Paid by the City of New York for Engineering and Legal Services—1925

(*Source:* Adapted from data compiled by the Association of Engineers of New York, Inc., from the New York City Budget for 1925 as officially adopted.)

Engineers as a class everywhere are lamenting the fact that they are mere employees, having little or no say regarding the conditions under which they must work or the remuneration they must accept. They realize this is an effect resulting from the common objectionable cause—overproduction—which ruins any industry as well as any profession.

Mr. Field wishes statistics compared between owners and employee members of the several professions, while at the same time revealing the weakness of such figures as are probably obtainable, i.e., a few employer engineers taking full advantage of the glutted market of their colleagues against professions consisting largely of independent practitioners.

The article objects indirectly to restricting the engineering field to properly trained and qualified engineers while at the same time avoiding the admission of the powerful control other professions have over the respective markets for their services through legal instruments.

Mr. Field points out that mere skill is an insufficient trading point. He obviously recognizes that engineering talent is so abundant it is no longer an important factor in the market price for engineering services.

Personality, that illusive thing considered by some a desirable quality, by others, a form of hypocrisy, whatever it may be—Mr. Field emphasizes—is necessary to acquire to be a successful engineer. Will such type of engineering talent solve the problems to prevent St. Francis Dam disasters?

A rare bit of the type of data Mr. Field asks for has been compiled and shown below. While in the writer's opinion it does not show the full difference in compensation, it certainly shows the trend. In such comparisons the conclusion must not be drawn that the legal profession is overpaid, but rather that the engineering talent is greatly underpaid.

The most significant condition disclosed by the chart is the large number of well-paid positions in the legal service as contrasted to the very few in the engineering service, thus showing conclusively the little opportunity the future offers to the young engineer in the City's service.

Thomas H. Normile.[1]

New York, N. Y.

Why Go to College?

To the Editor:

The article headed "Why Go to College?" in the July issue is so unfair that it deserves a wealth of denunciation.

It is an acknowledged fact that three out of four persons who are sent to college today—note that I use the word "sent"—would make more of their lives if they went into some useful occupation in their home town. These persons are turned loose to clog the machinery of civilization, to become parasites upon those who do toil and think. In business, industry, and public affairs, these idlers make use of a loud-voiced advertising to worm into soft positions at high salaries, solely on the strength of four years spent in college.

Every one who faces things squarely will acknowledge the truth of the above assertion. This is no criticism of colleges—far from it—but it is a criticism of the trend toward the marked leniency to the man who has been dragged through four years of college life. For those who work their way through college and the small minority who appreciate the responsibilities which opportunity places upon them, I have the highest respect—those men correspond to the college men of older days.

Before terming the non-college man an "unimaginative drudge" and the average college man an "interesting personality" gifted with social graces and "one of ours," let me suggest the application of a little engineering to the two.

Inasmuch as upwards of $10,000 and four years of time have been lavished upon the college man, he should be able to out-work and out-think his less fortunate brother. A person to whom ten talents are given should make more of a showing with them than the one-talent man—but does he do it?

The only fair basis of comparison is a common level. The college man invariably *starts* in at a position at a higher salary than his experienced predecessor, is given shorter hours, demands and gets more assistance, and is allowed greater freedom. Any poor stick can make a showing if he is allowed a lavish hand—it takes real ability to make a showing without raising the expenses of carrying on a business or a department. That is what the non-college executive has done in practically every case.

[1] Research Engineer, Dept. of Agriculture. Jun. A.S.M.E.

Until the college man proves that he can swing the duties of a position under all the discouragements and handicaps piled in front of his brother, his B.A. in tobacco and M.A. in social graces are but sounding brass.

It has long been a mystery to me why industries that split minutes on every operation in the plant and have piece-worked everything down to closing windows do not turn their attention upon the offices, where real savings could be made. To a person who is accustomed to going into the whir of industry with an eye single to small savings, it is little less than appalling to note the long rows of well-dressed young men who stroll into offices about nine and leave about four, having spent approximately half of their time in visiting and idling. The late Mr. Frank Gilbreth did wonders with the art of brick laying but that is nothing to the savings for industry that he could have made had he turned his attention to the college type of "worker."

If these same men were compelled to labor a few years in a gang of producers (not the comedy stuff of learning a business in six months, that spatters our news items) then they would become real men of value and vision in an office. At one of the A.S.M.E. round tables, at New Haven, a British engineer told that at least one of their universities intended to refuse admission to prospective engineering students unless they had had three years or more of practical experience.

All of us would like to be a Hoover or a Lindbergh but few of us stop to think that the qualities which raised these men to the pinnacle were hammered out during long years of "unimaginative drudging" under conditions where each had to stand and deliver.

In these days of profitless prosperity, so-called, it is up to us as mechanical engineers to seek out fearlessly the loophole whence all the profits of intensive industry have gone. Assuredly, it is not in the production end.

DONALD A. HAMPSON.[2]

Middletown, N. Y.

Better Riveted Joints

TO THE EDITOR:

The editorial on riveted joints is pertinent and well taken.

There are a number of angles from which this matter can be approached.

The characteristics of riveted joints in plates of moderate thickness, that is to say, up to $^3/_4$ inch to 1 inch have been pretty thoroughly examined and analyzed during the past years. The characteristics of riveting of thicker plates up to 2 inches, which is about the maximum practicable, are, I believe, not quite so well known. It is in these thicker plates that welding is more likely to displace the riveting than in the thinner plates.

Because of commercial reasons if for nothing else, since it is still much cheaper to make riveted joints than welded ones, the older process will persist for an indefinite period for the lighter plates. Furthermore, the technique of autogenous welding is still in process of development and has some way to go before it is generally acceptable for high-class, high-pressure boilers.

E. R. FISH.[3]

New York, N. Y.

TO THE EDITOR:

Undoubtedly, welding will never completely supersede riveting, and it behooves the advocates of riveted joints to make a closer study and establish standards more in keeping with actual practice. A couple of years ago, the hydraulic section of the N.E.L.A. published a complete report on penstocks, head gates, trash racks, etc., in which they showed several examples of riveted joints which the power companies on the Pacific Coast have been using. Up to the present, nearly every manufacturing company and engineering office have been using their own standards. There has not been, to the writer's knowledge, any definite standard set for riveted joints on penstock work. As a consequence, there have been several failures of riveted joints in the field, on this class of work, and innumerable cases where rivets are placed in single shear and the bending on the rivets figures extremely high.

The question of welding penstocks and spiral casings for hydraulic turbines has been coming up on nearly every job—that is, to weld instead of calk the joints. There are some very strong advocates of calking who claim that unless very careful welding work is done, the heating of the plates will pull on the riveting.

We find a decided reluctance on the part of the power companies to accept welded penstocks until more experience has been gained and better welding developed. Undoubtedly, within the next five years this reluctance will have been pretty well overcome and a large number of machine parts will be made of structural and plate steel instead of castings. Every large manufacturing plant will have to replace its foundry, to a large extent, with a plate and structural fabricating shop. To the writer, it seems that better riveted joints will be imperative to meet this progressive step, because there will arise a great many cases where welding cannot be used satisfactorily and where it will be necessary to rivet, even though part of the structure may be welded.

The writer thinks it would be well for the A.S.M.E. to appoint a committee to go into this matter and establish definite standards on the best riveting practice that can be found.

D. J. MCCORMACK.[4]

York, Pa.

TO THE EDITOR:

The recent editorial on "Better Riveted Joints" is timely and should start a movement in the Society toward bringing this important subject up to date.

The Boiler Code covers the more usual types of riveted joints, and for regular boiler work each manufacturer has worked out his own standard joints. But today more and more variations from these are needed to take care of the many special requirements on plate work.

To overcome the present confusion on rivet types for various purposes there is a very great need for standardization, if not research. Different joints and rivet shapes are being specified for the same class of work. It is usual to expect one to be better than the others.

For instance, on work where a corrosive liquid is held under pressure, one can see specifications that vary from the ordinary riveted joint to special ones using swell-neck rivets, oversize heads, and even heads of unusual shape, such as pan heads. None of these is standard and there are no regularly accepted specifications for them.

The matter of tolerance of rivet and hole diameters is another item that is left to the manufacturer. On high-pressure work closer tolerances than the usual ten-thousandths is generally specified. This is also true on oil stills as well as high-pressure boilers. The Society could at least indicate what should be considered good engineering practice in this regard.

Another item on which there is no accepted standard is the maximum limit of rivet pitch adjacent to a calking edge. When inside calking only is to be done, this becomes an important question. Experience indicates that this maximum limit is less for high-chromium plates than for steel.

[2] M.E., Morgan & Wilcox Mfg. Co. Mem. A.S.M.E.

[3] Vice-President, Heine Boiler Co. Mem. A.S.M.E.

[4] Sales Manager, S. Morgan Smith Company. Mem. A.S.M.E.

Special reaming or head shape for rivets might be worked out for use with some of the more difficult special alloys being used more and more today. Any one driving chromium-steel rivets will appreciate the importance of this.

A canvass of the present rivet and riveted joint situation would bring to light many surprising things. Publishing more up to date data would greatly benefit the industry as a whole.

G. W. NIGH.[5]

Coatesville, Pa.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and published in MECHANICAL ENGINEERING.

Below are given records of the interpretations of the Committee in Cases Nos. 576, 595, 598 (Reopened), and 599–602, inclusive, as formulated at the meeting on June 15, 1928, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

CASE NO. 576

Inquiry: Will the electric-resistance butt-welding method be acceptable under the provisions of the Boiler Code?

Reply: It is the opinion of the Committee that welding done by the electric-resistance butt method under pressure may be considered the equivalent of forge welding, as provided for in Par. P-186.

Note: It was the opinion of the Committee that a higher working stress may be allowable than that specified for forge welding, and a special committee was therefore appointed to submit recommendations for a revision of the Code in this respect.

CASE NO. 595

Inquiry: Will it meet the requirements of the Code for Low-Pressure Heating Boilers to insert staybolts in welded steel heating boilers that consist of $^3/_4$ in. button-head rivets, the head end of the rivet to be on the outer surface of the water leg and welded around the periphery of the head, while the inner end of the rivet is welded to the furnace sheet as provided for in Par. H-83?

Reply: If the button-head end of the rivet which is attached by welding is welded in accordance with the requirements of the Code, the construction will conform to the requirements of the Code.

CASE NO. 598 (REOPENED)

Inquiry: Will it be permissible, under the rules of the Power Boiler Section of the Code, to use for cleanout openings a special type of plug which fits into a thimble or nipple threaded into the water leg, instead of the usual form of threaded opening with pipe plug as referred to in Pars. P-266 and P-267? It is pointed out that with this construction there is no danger of crossing threads in inserting the plugs and that the tightness is dependent upon seating surfaces rather than tapering threads.

Reply: There is nothing in the Code to prevent the use of the type of plug described, provided it will meet the requirements of the Code where reference is made therein to such plugs.

CASE NO. 599

Inquiry: Does the requirement in Par. P-328 for safety latches or fastening devices apply to the firing doors of water-tube boilers which are equipped with down-draft furnaces of the water-grate type?

Reply: While Par. P-328 of the Code is specific in regard to firing doors for water-tube boilers, in this case the boiler would be inoperative unless the firing door were open. The Committee recommends, therefore, that some form of door be used that is capable of being retained with a substantial and effective latching or fastening device, or that a type of door be used which will admit air yet will prevent the gases from the furnace from being blown directly outward in case of pressure within.

CASE NO. 600

Inquiry: Is Par. P-301 of the Code intended to prohibit the use of a shut-off valve between the outlet of a boiler and its superheater when the latter is used on a boiler of the portable type? It is pointed out that on a steam-shovel installation, without such a shut-off valve, it will be necessary to shut down the boiler in case of a gasket leak between the superheater and the throttle valve.

Reply: It is the intent of Par. P-301 to allow the superheater connection to be operated without a stop valve, but it was not intended to prevent the application of the stop valve in this connection if so desired. It is allowable to use a stop valve in this connection provided the full safety-valve capacity required is installed on the boiler and no credit is taken for the capacity of the required safety valve or valves on the superheater.

CASE NO. 601

Inquiry: Is it the intent of Par. U-3 of the Code that lifting devices must be attached to all safety or relief valves? Attention is called to the fact that it is not customary to equip water-relief valves with lifting devices and Pars. H-50 and H-103 of the Heating Boiler Code state specifically that such lifting devices are not required for hot-water relief valves.

Reply: Par. U-3 was formulated with special reference to requirements for relieving pressure of air or other gases that are not noxious, and it is the opinion of the Committee that it need not be applied to relief valves for use on connections to water-pressure vessels. A revision of the Code in this respect is contemplated.

CASE NO. 602

Inquiry: Is it permissible to use a constant of 135 in the formula given in Par. H-21 of the Code for ordinary staybolts welded into plates forming the water leg of a boiler? It is pointed out that these staybolts do not exceed 6 ft. in length.

Reply: In the recent revision of the definition of the constant 135 in Par. H-21, it was the intent that welded stays computed with this constant should be of a length between supports in excess of 120 diameters. A further revision of this paragraph to incorporate this limit is under consideration.

[5] Chief Engineer, Coatesville Boiler Works. Mem. A.S.M.E.

Revisions and Addenda to Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later on in the proper place in the Code.

During the past two years the Boiler Code Committee has received and acted upon a number of suggested revisions which have been approved for publication as addenda to the Code. These are published below, with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticisms and comment thereon from any one interested therein. Discussions should be mailed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

After 30 days have elapsed following this publication, which will afford full opportunity for such criticism and comment upon the revisions as approved by the Committee, it is the intention of the Committee to present the modified rules as finally agreed upon to the Council of the Society for approval as an addition to the Boiler Construction Code. Upon approval by the Council, the revisions will be published in the form of addenda data sheets distinctly colored pink, and offered for general distribution to those interested and included in the mailings to subscribers to the Boiler Code interpretation data sheets.

For the convenience of the reader in studying the revisions, added matter is in small capitals and deleted matter in smaller type.

PAR. H-4. REVISED:

H-4. The maximum allowable working pressure on the shell or drum of steel-plate steam-heating and hot-water boilers shall be determined by the strength of the weakest course, computed from the thickness of the plate, the tensile strength stamped thereon WHICH SHOULD BE THE MINIMUM SPECIFIED [as provided for in Par. S-17 of Section II of the Code], the efficiency of the longitudinal joint, or of the ligament between the tube holes in shell or drum (whichever is the least), the inside diameter of the course, and the factor of safety, but in no case shall the pressure on which the factor of safety is based be considered less than 30 lb.

$$\frac{TS \times t \times E}{R \times FS} = \text{maximum allowable working pressure, lb. per sq. in.}$$

where TS = MINIMUM ultimate tensile strength stamped on shell plates [as provided for in Par. S-17 of Section II of the Code, lb. per sq. in.]

t = minimum thickness of shell plates in weakest course, in.

E = efficiency of longitudinal joint or of ligaments between tube holes (whichever is the least)

R = inside radius of the weakest course of the shell or drum, in.

FS = factor of safety, or the ratio of the ultimate strength of the material to the allowable stress.

For new constructions, FS in the formula = 5.

PAR. H-5. REVISED:

H-5. Specifications are given in Pars. S-1 to S-263 of Section II of the Code for the important materials used in the construction of boilers [and where so given the]. Material [s herein mentioned] for [boiler] parts OF LOW-PRESSURE HEATING BOILERS required to resist internal pressure, FOR WHICH SPECIFICATIONS HAVE BEEN PROVIDED shall conform TO THOSE SPECIFICATIONS [thereto] except as OTHERWISE specified herein [for autogenously welded boilers].

PAR. H-6. REVISED:

H-6. Steel plates USED for any part of the boiler SUBJECTED TO [where under] pressure, [also manhole and handhole covers and other parts subjected to pressure] (and FOR braces and lugs) [when made of steel plate] shall be of flange or firebox quality IN ACCORDANCE WITH [as designated in] the Specifications for Steel Boiler Plate, except PLATES [for base metal as specified] for autogenous welding AS HEREIN SPECIFIED (SEE PAR. H-74).

PAR. H-8. REVISED:

H-8. *Tensile Strength of Steel Plate.* In determining the maximum allowable working pressure, the tensile strength used in the computations for steel plates shall be that stamped on the plates as herein provided, which is the minimum SPECIFIED [of the stipulated range, or 55,000 lb. per sq. in. for all steel plates except for special grades having a lower tensile strength].

PAR. H-74. REVISED:

H-74. *Material for Base Metal.* The base metal composing the plates of autogenously welded [steel] heating boilers shall be of [good] weldable FLANGE OR FIREBOX quality [and shall be made by the open-hearth process] conforming to the requirements of [the specifications for forge welding] Pars. H-122 [121] to H-136 INCLUSIVE [or to those for flange and firebox classes of steel given in Pars. S-5 to S-17 of Section II of the Code, provided the carbon does not exceed 0.20 per cent].

PAR. U-20. REVISED:

U-20. *For Internal Pressure.* The maximum allowable working pressure on the shell of a pressure vessel shall be determined by the strength of the weakest course, computed from the thickness of the plate, the efficiency of the longitudinal joint, the inside diameter of the course, and the maximum allowable unit working stress.

StE/R = maximum allowable working pressure, lb. per sq. in.

where S = maximum allowable unit working stress in lb. per sq. in.
= 11,000 lb. per sq. in. for steel plate stamped 55,000 lb. per sq. in., 10,000 lb. per sq. in. for steel plate stamped less than 55,000 lb. per sq. in., and 9000 lb. per sq. in. for material used in seamless shells.

t = minimum thickness of shell plates in weakest course, in.

E = efficiency of riveted longitudinal joint [per cent]

R = inside radius of the weakest course of the shell, in., provided the thickness of the shell does not exceed 10 per cent of the radius. If the thickness is over 10 per cent of the radius, the outer radius shall be used.

NOTE: When the safe working pressure for welded or brazed vessels is to be determined, E will be omitted from the formula and the values for S in Pars. U-68, U-82, or U-94 will be substituted for the values given above. For seamless shells, E equals 100 per cent.

A Correction

ON page 561 of the July issue in the article on "Maximum Allowable Unit Working Stresses for Fusion-Welded Joints" the formula should read cube root of $\frac{E}{10}$ instead of the square root. In the second footnote on the same page the words American Welding Society should read American Society for Steel Treating.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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Contributions of interest to the profession are solicited. Communications should be addressed to the Editor.

BY-LAW: The Society shall not be responsible for statements or opinions advanced in papers or.... printed in its publications (B2, Par. 3).

Reforms in Steam-Boiler Terms

ELSEWHERE in this issue is published "A Suggestion for Rating Steam Boilers," which is a plea for a revision of terms used in rating steam boilers. The question of the revision of some time-honored engineering terms which were introduced, it now appears, ill-advisedly, is agitated by someone almost every time engineers get together to discuss steam boilers and boiler performance. These terms come glibly to our tongues because we have used them so often, and although most of us recognize their inaccuracy or inadequacy in expressing what we really mean, and students particularly are confused by a terminology which has out-grown its formal definitions, we persist in using them because a thorough-going revision has never received the necessary enthusiastic support. Individual reformers have lifted their voices in protest, practical-minded men have suggested definite alternatives to our present terms, but these efforts have borne little fruit because they have lacked proper organization.

The paper by Messrs. Shoudy and Jacobi, which we publish in this issue, was presented at a meeting of the Metropolitan Section of the A.S.M.E. and stimulated a valuable and extensive discussion, a very brief summary of which will be found at the end of the paper. Regardless of what may be the individual opinions of engineers as to the wording of definitions, the choice of a name for a term, or the advisability of emphasizing "furnace factor" or "excess air," there probably exists a fundamental desire for standardization and revision of definitions of terms. If interest in forwarding such standardization and revision is sufficiently aroused, we may hope for the formation of a strong and active committee which will undertake the long-postponed job. Such a committee will find itself in possession of the extensive discussion of the paper referred to containing many valuable suggestions from competent leaders in the field. The Society has also other papers expressing the points of view of other authors. There is, therefore, a splendid beginning already made, and any group of individuals which wishes to undertake this important work will find the regularly constituted agencies of the Society ready to help.

If you approve of such kinds of reforms as Messrs. Shoudy and Jacobi suggest, why not write your views to the Secretary of the Society.

Diesel Fuel Oil Specifications

FROM time to time, the point has been made by oil marketers and oil-engine users, that the various engine builders' recommendation as to the proper fuel to be used in a Diesel engine was too stringent, as well as non-uniform. At the National Meeting of the Oil and Gas Power Division, at Penn State College in May, oil specifications were the chief subject of discussion. Those attending the meeting, including engine builders, users, and oil marketers, united in a request to the Society that a committee be appointed to draw up a proper and reasonable fuel-oil specification such that all the engine builders would recommend this oil in their own engines.

The Executive Committee of the Division has given close study to this subject and has recommended to the Research Committee of the Society a list of engineers to make up the standardized Fuel-Oil Committee. These men include representatives of engine builders, large users, and oil marketers. It is the intention to have this committee cooperate with a committee representing the Diesel Engine Society, the association of engine builders.

If a standardized specification can be evolved, a saving of millions of dollars yearly will result. The subject has many angles and a speedy solution is not to be expected, but the committee can and will find it.

L. H. MORRISON.[1]

"Research" in the Comic Papers

THE misuse of the word research was the subject of an editorial in the August issue of MECHANICAL ENGINEERING. In it we presented the possibility that the word might reach the comic state. Now we find that previous to the printing of our editorial the subject had been discussed in one of the weekly comics. *Judge* for June 28, 1928, deals with the use of this in a manner which lends itself to serious consideration. We take pleasure in printing three paragraphs from it.

> In business, as in diet and parlor games, we are prone to snatch at fads. A few years ago it was efficiency. Today it is research. And a whole lot of those who fall for the selling talk about research never quite know what they are buying.
>
> Much of what passes by the name of research, in advertising for instance, is spurious. Starting with a conclusion and piling up data with a pretense of supporting it, is not research. Starting with a fact, linking more facts to it, letting them come to life, articulate themselves, and drag you along with them regardless of where they take you, is the only kind of research worth the time of any honest person. A purist might say that a good simple way of telling which kind a man is talking about is by his pronunciation. If he calls it re*search*, it's the real article. If he calls it *re*search, it's the bunk. But this is perhaps a risky rule, because there are large sections of the country in which accents are loosely distributed. At a meeting of the National Research Council itself Edwin E. Slosson kept a record of pronunciation of the word for one day and found that exactly half of the experts put the accent—incorrectly—on the first syllable.
>
> The safest procedure is to pay no heed to the man who tells you in advance what he expects to prove, but to sit at the feet of him whose guiding principle is "First let's get the facts."

[1] Associate-Editor, *Power*, McGraw-Hill Publishing Co., New York, N. Y. Mem. A.S.M.E.

A Question of Ethics

An interesting question has been submitted to the Committee on Professional Conduct. A newly established firm of consulting engineers is building up a practice. One of their more important clients suggests that he can extend their clientele provided he is supplied with letters of recommendation from responsible people for whom the newly established firm has designed and installed equipment. The employer under whom the newly established firm gained its experience is perfectly willing to recommend them; but letters from users rather than manufacturers are desired. Should the firm solicit letters from engineers for whom they designed equipment during their previous employment, provided that their ability only and not the product of their former employer is involved?

Informality of procedure caused by the question necessitated an informal reply which is expressed on the following quotation from one of the members of the Committee on Professional Conduct.

"I can see no reason why these gentlemen should not use the experience which they obtained while in employment as a recommendation for their ability to do similar work on their own responsibility as consulting engineers. Of course, it would be unethical to use this experience to the disadvantage of their previous employer, but since the employer has expressed himself as being favorably disposed toward their present professional activity, it would seem to be a hardship for them to have to avoid the use of this experience as a means of getting started on their own account."

High-Pressure Boilers

The trend of pressure vessels is unmistakably toward higher pressures brought about in the effort to secure as high an efficiency of heat transfer as possible with the materials and equipment that are available. This condition will be noted more prominently in the fields of steam generation and petroleum distillation, and the designer's problem has involved radical departures in fabrication as a result.

A consideration not to be ignored is the rivet used. It has been found repeatedly that the weakness of high-pressure vessels after comparatively short service lies in the occurrence of leaks at the rivets. Usually this is not an indication of poor inspection or fabrication but is due to the imperfections in the rivet itself, or the hole into which it is driven.

The ordinary boiler rivet is likely to have die marks and fins under the head and along the shank; it is apt to be out of round; to have small rolling seams; and to be coated with a forging scale. Any one of these conditions will cause trouble sooner or later under the action of high working pressures, and the specifications should be so written as to preclude their presence. In keeping with modern advanced design, rivets should be produced by a forging process and treated to remove all scale, fins, seams, and die marks. The shanks should be accurately round and fitted into carefully reamed holes with a clearance of no more than $^1/_{32}$ inch. A moment's consideration will reveal the folly of drilling and reaming holes in a boiler shell to be filled with inaccurate, scaled rivets. A full metal-to-metal contact between the rivet and the plate is necessary for tight work and such a result can be accomplished only by the use of a clean perfectly formed rivet. The control of this factor in the manner indicated will furnish a warranty for prolonged satisfactory performance, because the vessel fabricated in such a manner will equal the designer's expectation of a solid one-piece unit of uniform strength that depreciates no faster at one place than another.

A Case for Arbitration

A manufacturer of boiler-room equipment was sued for damages of over $100,000 because it was claimed that an installation of his equipment in a furnace blew out the tubes of a boiler. The cost of the equipment was only a small percentage of the damage involved. The jury disagreed after a battle of experts. The case cost the litigants large amounts of time and money.

This is a type of case which offers many difficulties to a simple and direct solution in the law courts. The more efficient settlement of disputes of this character is made possible through the arbitration machinery now available throughout the country but, unfortunately, this is not generally known.

The American Arbitration Association with headquarters in New York City has been advocating for many years the passage of comprehensive arbitration laws in the various states, in harmony with the United States Arbitration Act. These laws permit the insertion in contracts of a clause under which the parties may stipulate that any controversy later arising under the contract shall be settled by arbitration according to the laws of the state. When a controversy arises, the parties agree on the arbitrators but, if they fail to do so, the courts will appoint the arbitrators whose findings, when confirmed by the court, are recorded as judgments, provided certain simple procedural requirements are complied with. The American Arbitration Association has a national panel of over 4000 arbitrators and stands ready to assist in providing skilled men of judgment as arbitrators.

The use of the arbitration method in the case briefly mentioned above would have simplified the procedure and reduced the costs to the litigants.

Arbitration laws that are fully effective are now in operation in Massachusetts, New Jersey, Pennsylvania, California, Oregon New York, and Louisiana. In the last-mentioned state, Governor Long signed a new law on July 23, 1928, which was quite similar to the Draft State Arbitration Act prepared by the American Arbitration Association. Engineers in the industries of these states will find much of interest in the law.

Back to Democritus

It is expressing no new thought to say that the world, or at least Science, was the loser when the schoolmen of the renaissance saved Plato out of the wreck of Greek enlightenment and allowed Democritus to sink into oblivion. In the age-long conflict between materialism and idealism, the latter has invariably come off the victor, having as allies whatever formal religion has existed at the time and the natural predilection of the so-called educated classes of society for subjective rather than objective philosophy. Had the scientific method as we conceive it today, with its insistence that hypotheses be subjected to the most rigid and searching tests of experimentation, even to the point of doubting the validity of mathematical deductions which run counter to observed facts, been accepted rather than scorned by early philosophers, it is possible that the physical sciences would have developed earlier and more rapidly.

Within the short span of a few generations, modern scientists have brushed away much of the dust of ignorance and misinformation which befouls the mirror of truth and have validated many of the theories of Democritus which centuries of neglect almost doomed to permanent extinction. The natural curiosity about the structure of matter which has led zealous searchers after truth into such extraordinary realms of the infinitesimal is bearing fruit so abundantly that educated men find difficulty in keeping in step with the advances and in comprehending their meanings.

The quantum theory, which is the subject of an article to be found elsewhere in this issue, has been discussed by scientists for nearly a generation. It offers an explanation of many phenomena which have become commonplace in our modern life—the radio and the X-ray, for example—and it brings into use the latent potency of subatomic activity which is beginning to be a tool for the engineer, as shown in the work of the metallurgist.

Engineers as yet think in molecular terms. The thermodynamics which is taught in our schools, for instance—at least in the elementary courses—is content with subdivisions of matter no smaller than the molecule, and with conceptions of energy and radiation which served our fathers because none other was known. The quantum theory is mentioned, if at all, with the deference which ignorance always pays to superior knowledge, and there is a suspicion that universal opinion concedes these new-fangled notions as proper enough for the physicist but unprofitable for the engineer. The time has come for the modernizing of engineering courses to include a clearer understanding of the advances of modern physics and their effect on engineering.

The practice of engineering has always outrun its science. Watt built a very respectable steam engine before Meyer had formulated the first law of thermodynamics and Carnot the second and before Regnault had investigated the properties of steam. The secrets whose revelation will unlock the doors of understanding elude us who persist stubbornly in fields of sensory phenomenon and who labor under the handicap of classical theories which have rendered us dogmatic.

And so, we are back again to Democritus who lived in the fifth century before the Christian era and whose theories of the atomicity of matter were so accurately prophetical. What one of the present age wonders is why twenty-four centuries had to pass before educated men could attack successfully the homely problems which lie in the material sciences, and what progress we would now be witnessing had our masters set our feet in more profitable paths. The lesson we can draw from it is to maintain an attitude of mind ever open to the acceptance of the eternal verities as they are revealed to us and to foster the work of those who search so zealously for them.

Edwin Britton Katte

EDWIN BRITTON KATTE, former vice-president and manager of the Society, died at his home, Irvington, N. Y., July 19, 1928, after an illness which had lasted for more than a year.

Mr. Katte, the son of Colonel Walter and Elizabeth Britton Katte, was born in St. Louis, Mo., on October 16, 1871. His early education was obtained at Cutler's private school in New York City, and his professional education at Sibley College, Cornell University, from which he was graduated in 1893 with the degree of M.E. He received the degree of M.M.E. from the same institution in the following year.

From 1894 to 1896 Mr. Katte was employed as machinist and erector in the hydraulic works of the Henry R. Worthington Co., South Brooklyn, N. Y. Early in 1896 he entered the service of the New York Central & Hudson River Railroad, a connection which was to remain unbroken until the day of his death. His first duties were in connection with the building of the Park Avenue viaduct, New York City, and the installation of the turning and locking machinery of the four-track railroad drawbridge over the Harlem River. In 1898 he was appointed mechanical engineer in the engineering department of the railroad in charge of the design and construction of heat, light, and power plants, coaling stations and water supply.

In December, 1902, Mr. Katte was appointed electrical engineer and secretary of the Electric Traction Commission of the New York Central & Hudson River Railroad Company, under whose direction he had immediate charge of the electrical and mechanical engineering corps engaged upon the work of the electrification of the various lines of the company in New York City and vicinity. This was the first trunk-line steam railroad to have its entire through and suburban service hauled by electricity. The undertaking included two 30,000-kw. central stations which were among the first to use large-capacity turbo-alternators. The system included nine substations with batteries, extensive aerial and underground 11,000-volt transmission systems, 600-volt direct-current distributing systems, and 285 miles of third-rail. In the equipment were 73 of the most powerful, high-speed passenger electric locomotives constructed up to that time, and 211 all-steel motor cars which were the first ever constructed for a trunk-line railroad.

Mr. Katte's appointment as chief engineer of electric traction of the railroad came in November, 1906, when he was placed in charge of the design, construction, and operation of the electric traction system. In March, 1922, he was appointed consulting electrical engineer for the Cleveland Union Terminals Company, having charge of the design and construction of the electric traction systems entering this station, both for the railroads and for the electric interurban systems. In November, 1925, he became chairman of the committee having charge of the electrification of the freight service of the railroad company's West Side tracks in New York City, and in January, 1926, he undertook the duties of the chairmanship of the New York Central Lines Mechanical and Electrical Committee which coordinates the electrical and mechanical activities of all of the New York Central Lines.

Mr. Katte joined The American Society of Mechanical Engineers in 1895. He served it as manager and vice-president and as a chairman of its railroad committee and its Railroad Division. He was a fellow of the American Institute of Electrical Engineers and served on many of its important committees. As a member of the American Railway Engineering Association he served as a director, and as chairman of its committee on electricity for over eleven years. He served several terms as vice-president of the New York Electrical Society, as chairman of the electrical night committee of the New York Railway Club, as chairman of the electrical section of the American Railway Association, and as member of the committee on electrification of steam railroads of the National Electric Light Association. He was also a member of the American Committee on Electrolysis and American Committee on Inductive Coordination. He was a member of the University Club, the Transportation Club, the Century Association of New York, and the Ardsley Club, Ardsley-on-Hudson.

Mr. Katte contributed largely to the literature of engineering and read many papers before national technical bodies. He lectured before engineering classes at Harvard University, Stevens Institute of Technology, Cornell University and the Brooklyn Polytechnic Institute. He served as consulting electrical engineer to the Carnegie Foundation for the Advancement of Teaching, as an alumni representative of the College of Engineering of Cornell University, and as a member of the committee on university relations of the American Railway Association.

From 1917 to 1919 Mr. Katte held a commission as major in the Reserve Corps of the U. S. Army, but did not see active service because of his government employment as chief engineer of electric traction in the U. S. Railroad Administration. He was 1st sergeant and later 2nd lieutenant in the Irvington, N. Y., Home Guard, and served on Liberty Loan committees at Irvington and the New York Central Railroad, and on Red Cross, War Workers, and Y. M. C. A. committees.

Mr. Katte was married on January 26, 1907, in Irvington, N. Y., to Elva King, daughter of Thomas M. and Blanch Finney. He is survived by his wife and two children, Elizabeth and Edwin Britton Katte, Jr.

Extraordinary Aeronautical Meeting

The Second National Meeting of the Aeronautical Division Held at Detroit in Conjunction With the Air Olympics

THE second national meeting of the Aeronautical Division of the A.S.M.E., which was held at Detroit, June 28–30, in cooperation with the Detroit Local Section, was planned in conjunction with the Air Olympics held in that city on June 30. These two events brought together most of the prominent engineers and many others interested in aeronautics. About 400 members and guests registered at the meetings which were held at the Book-Cadillac Hotel.

Frederick H. Low, Chairman of the Detroit Section, presented the address of welcome when the meeting opened on Thursday morning. He spoke of the far-reaching effect which aerial navigation has had in correcting misunderstandings between the people of the world due to the elimination of the isolating effect of distance, and introduced Morgan B. Smith of the General Motors Corporation of Detroit who acted as chairman of the meeting.

Transport Session

The first paper was presented by William B. Stout of the Stout Metal Airplane Company, Detroit, Michigan, who spoke on "Aviation as a Transport." Mr. Stout spoke of the spirit of cooperation and harmony which reigns in the plants of the airplane manufacturers who are working together for the good of the industry. Flying, he said, is a service business and gives the type of service in which speed is fundamental. He cited many instances to prove his point. In addition, he said, the airplane serves a purpose in covering the country that cannot be reached or that is not served by other means of transportation. He mentioned the movement for the cooperation of railroads with air lines and said that while the technique of night flying is not yet developed, it is developing quickly so that before long passengers will be using airlines day and night as they use railway trains. He concluded his address by mentioning various psychological and engineering problems with which the aircraft manufacturer has to deal.

James G. Ray, Operations Manager, Pitcairn Aviation, Inc., Philadelphia, Pa., read the second paper entitled "Preparation of an airline for Commercial Operations."

The third address of the morning was delivered by the Hon. William P. MacCracken, Jr., Asst. Secretary for Aeronautics, Department of Commerce, Washington, D. C. Secretary MacCracken said that the only two bureaus of the Department of Commerce that do not have some immediate contact with the Department of Aeronautical Activities are the Bureau of Fisheries and the Bureau of Steam Boat Instruction. When the Air Commerce Act was passed in May, 1926, and the Department of Commerce was assigned the duties which were created under the act, an attempt was made to carry on these duties without the formation of new bureaus or divisions in the department. It was necessary, however, he said, to create two new divisions, one of which is known as the Air-Regulations Division and which has three sections; one for licensing and instructing airplane pilots and mechanics; another, the engineering section, to examine the stress analysis of planes; and the third, the medical division, which cares for the physical examination of pilots. In addition to the Air Regulation Divisions, he said, the Air Information Division was set up whose duty it is to compile statistics and answer inquiries. There is also an airport section which cooperates with municipalities in matters pertaining to airports. All of the rest of the aeronautical activities have been fitted into some of the existing bureaus or divisions of the Department of Commerce. Secretary MacCracken spoke in considerable detail of the work of the Department of Commerce as it touches aeronautics.

Session on Wood in Aircraft

The afternoon session was devoted to wood and was held jointly with the Wood Industries Division of the Society. George H. Fenkell of Detroit presided. The author of the first paper, Charles B. Norris, Chief Engineer, Haskelite Company, Grand Rapids, Michigan, was unavoidably prevented from attending and his paper, "Plywood as a Material of Aircraft Construction," was read by title.

T. R. Truax of the Forest Products Laboratory, Madison, Wisconsin, read a paper entitled "Gluing of Plywood." The paper discussed the glues used in aircraft and described the gluing operation and its application to different species of wood. The author made recommendations for the gluing of different woods with both animal and casein glues, giving data on glue-water proportions, glue-spread, temperature of wood, pressure to be applied to joint, and time the joint should remain under pressure. Following the presentation of his paper, Mr. Truax described the work of the Forest Products Laboratory and answered a number of questions upon it and his paper.

The third paper entitled "Application of Balsa Wood in Aircraft" was read by G. L. Weeks, Jr., of the Fleischmann Transportation Company, New York, N. Y. Mr. Weeks described how balsa grows, its physical appearance and structure, and compared it with other woods on the basis of density and its physical properties. He listed the number of parts of the airplane in which balsa is or could be used and closed with some remarks about the use of balsa as an insulator and its future prospects in air transportation.

Power-Plant Session

Simultaneously with the Wood Session, there was held a Power Plant Session at which Jarvis Webb presided. The first paper was presented by Harold Caminez of the Fairchild-Caminez Engine Corporation, Farmingdale, N. Y., and was entitled "Development and Technical Aspects of Fairchild-Caminez Engine." The paper provoked considerable discussion. Mr. Caminez explained the operation of his engine in which the usual mechanism for converting reciprocating to rotary motion is replaced by one which utilizes a double-lobed cam in conjunction with piston rollers. He also gave the history of the engine development and particulars of tests conducted on the engine.

The second paper of the session was presented by F. K. Kirsten, Professor of Aeronautic Engineering, University of Washington, Seattle, Wash., and was entitled "Cycloidal Propulsion Applied to Aircraft." Prof. Kirsten's paper described a type of propulsion which he devised after a study of the flight of gulls. He gave several examples of the application of his system to heavier-than-air and lighter-than-air craft. Following the paper a number of questions were asked which were answered by the author.

The third paper was by Dr. S. A. Reed of the Reed Propellor Company, New York, N. Y., and was read by title in the ab-

sence of Dr. Reed. The subject of his paper was "The Technical Development of the Reed Metal Propellors."

Aircraft Design

On Friday morning there were two simultaneous sessions, one devoted to design and the other to airways and airships. At the design session, Mr. Morgan Smith presiding, Lt. Carl Greene, Air Corps, War Dept. Materiël Division, Wright Field, Dayton, Ohio, read a paper on "Introduction to Wing Flutter." After defining wing flutter and analyzing the evidence accumulated as to the conditions under which it occurs, Lt. Greene discussed particulars of his study of the torsional oscillations of an airfoil. This was followed by the aerodynamic considerations involved in the problem. In the discussion which followed, Prof. F. Polaski, of the University of Michigan, contributed largely.

The second paper of the session on "Design of Commercial Airplanes" was presented by Mac Short, Vice-President, The Stearman Aircraft Company, Wichita, Kansas. Mr. Short showed how commercial airplane design grew out of the OX engines which were available at the end of the war. He discussed production problems and expenditures and described progress which was being made in design and showed how commercial airplanes must be built on a different basis than military planes.

The third paper in the session was by F. Handley Page, London, England, and was presented by Prof. Alexander Klemin of New York University, New York City. Mr. Page's paper, which was entitled "Slotted Wings," had been presented on May 30, 1928, before the Royal Aeronautical Society as the sixteenth Wilbur Wright Memorial Lecture and described in considerable detail Mr. Page's experiments on slotted wings.

Airways and Airships

At the session on airways and airships, William B. Mayo, Chief Engineer, Ford Motor Company, Detroit, Mich., presided. Dr. Carl G. Rossby, Chairman of the Daniel Guggenheim Committee on Aeronautical Meteorology, U. S. Weather Bureau, Washington, D. C., presented the first paper entitled "Meteorological Service for Commercial Airways." The purpose of meteorological service for commercial airways, it was pointed out in the paper, was to provide safety and efficiency in operation. The regular stations of the U. S. Weather Bureau, having been established before the use of airplanes, were too far apart to serve in supplying adequate weather information for airways and the Post Office Department therefore had organized a special network of weather observing stations along airways so that a pilot preparing a flight from one city to another could receive in advance information on the kind of weather he was likely to encounter on the way. Dr. Rossby used as an example some of the flying routes on the Pacific Coast and showed how one route between two cities might be unfavorable while another was favorable and how these routes could be chosen by the pilot because of the information reported to the airports. He showed how the collection and exchange of weather reports along the airway is handled by telephone and pointed out that caretakers at landing fields, watchmen in fire departments, and men in similar occupations can be easily trained to report the necessary observations. Dr. Rossby was unable to present his paper in person. C. G. Andrus, meteorologist in charge of the Hadley Airport, New Brunswick, N. J., discussed Dr. Rossby's paper.

"The Status of the Airship in America" was the title of a paper by Gilbert Betancourt, an engineer formerly with the Aircraft Development Corporation of Detroit, Michigan. Mr. Betancourt made a plea for greater public interest in the airship and showed how this country is lagging behind Germany and Great Britain in the development of heavier-than-air craft. He discussed some of the technical features of the design and construction of airships. This paper provoked considerable discussion to which, among others, Dr. Karl Arnstein of the Goodyear Zeppelin Corporation, Akron, Ohio, contributed.

The third paper of the session was by Carl B. Fritsche, Vice-President, Aircraft Development Corporation, Detroit, Mich., on "The Inherent Limits of Application of the Airships and Airplane." To the discussion which followed, W. F. Gerhardt of the Aero Research Corporation, Dayton, Ohio, and Prof. C. A. Norman, Ohio State University, Columbus, Ohio, contributed.

The General Session

The final session of the meeting was held Friday evening. Brig-Gen. William E. Gillmore, Chief, Materiël Division, Wright Field, Dayton, Ohio, presented a paper on "Military Aviation," which was a survey of the development of engineering materials for aviation uses, the air-cooled engine, and bombing equipment.

"Scientific Studies of Bird Flight" was the title of the second paper which was presented in French by Prof. Maurice Boel of Charleroi, Belgium. The paper was illustrated with a film which showed in rapid and slow motion pictures the flights of birds studied by Professor Boel. The paper which Professor Boel presented was prepared from an extensive manuscript on natural flight which considers not only the flight of birds, but all mammiferous animals and certain winged fruits and seeds. Prof. Alexander Klemin of New York University, New York, N. Y., commented extensively on Professor Boel's paper and answered the questions which it raised.

The last paper was by Col. B. E. Clark, Buffalo, N. Y., entitled "Aircraft Engineering Aspects of a European Trip." The paper was illustrated by lantern slides and showed the technical features of some of the European airplanes.

Banquet Outstanding Event of Meeting

The banquet held Thursday evening at the Grand Ball Room of the Book-Cadillac Hotel was the outstanding event of the meeting. President Alex Dow acted as chairman, with Harvey Campbell, Vice-President of the Board of Commerce, presiding as toastmaster. The speakers were Charles L. Lawrence, President of the Wright Aeronautical Corporation, and the Hon. William P. MacCracken, Jr. A delightfully interesting part of the banquet program was due to the toastmaster's calling on a number of celebrated aeronautic pilots, engineers, and executives for short talks. The banquet meeting was attended by several hundred visiting and local aviationists, and was conducted jointly with the Detroit Board of Commerce Aero Olympics Committee.

There were on exhibition several famous aeronautic trophies that were competed for in the air events of Saturday. The banquet closed with a showing of a motion picture of flights of birds taken by Prof. Maurice Boel of Charleroi University, Belgium.

The Air Olympics

On Saturday, June 30, the visting members were guests of the Detroit Board of Commerce at the Ford Airport where they witnessed the Air Olympics. The first event was the fourth international reliability airplane tour in which over twenty different makes of American airplanes competed in a 6000-mile tour for the Edsel Ford trophy. The second event at the airport was the Boys' National Model Airplane contest and exhibition of gliders that were recently brought from Germany. The last event was the James Gordon Bennett International Balloon Races, oldest of all the aeronautical sporting classics in the world, in which twelve balloons participated. Seven nations were represented.

Book Reviews and Library Notes

THE Library is a cooperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references on engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The Steam Engine

Reviewed by L. C. Loewenstein[1]

Die Dampfmaschine (The Steam Engine). By Dr. M. F. Gutermuth. Julius Springer, Berlin, 1928. In three sections (four volumes), 1635 pp., over 2000 figs., 86 lithograph diagrams, and 31 charts, 300 m. ($75).

THESE four volumes are by far the most important and complete publication on the steam engine as yet produced. The work is divided into three sections: Vol. I, Theory, Calculations, and General Constructions; Vols. II and III, Existing Designs; Vol. IV, Experimental and Test Results.

Vol. I is in two parts. The first part deals with the thermodynamics of the steam engine, and is presented in an unusually clear manner. The fundamental laws are not only well explained but their applications to actual machines are shown in great detail. This seems to be the only proper way of fully understanding the theory, by carrying the practical embodiment of the subject with the theoretical discussions. The seemingly many contradictions between what theory calls for and what practice gives are thereby made understandable in a very convincing manner. The text includes simple and multiple-expansion engines both of the horizontal and vertical types, condensing and non-condensing, high-pressure and high-superheat, stage-reheating, steam-extraction and high-back-pressure and low-pressure units, and uniflow engines; and it shows the influence of pressure, temperature, speed, degree of compression, variations of cut-off and load and vacuum in an exemplary manner. The text is not wholly confined to steam engines but covers heat engines in general, especially the Diesel engine, and rightly so. Particularly pleasing is the treatment of the second law of thermodynamics as it is applied to the utilization of energy for large energy drops or ranges.

The second part takes up the structural features of the steam engine in great detail, discusses the materials used in their construction, their general design, and the kinematics and dynamics of all their moving elements. All the necessary strength and stress calculations are given, and in the analysis of stresses especial excellence is shown. The subject of mass balancing is well treated. The various valve gears and governors employed in steam-engine practice are fully shown and discussed. The theory and design of condensers and their auxiliaries are excellently presented.

Vols. II and III cover the existing designs of steam engines in every detail, and what is of such great importance, they give a most comprehensive analysis of all the dynamic and kinematic actions and the proper functioning of the various machine parts. No book dealing with any mechanisms has ever presented such a subject in as clear and understandable a manner. The illustrations are admirable; they meet all the requirements of shop drawings except that they omit those dimensions and details always necessary on such drawings but which in this case would have only added confusion or at least unnecessary labor on the part of those studying the vital and fundamental requirements of such designs. The designs given are those of the leading European manufacturers and include some American practice. Vol. II covers mostly the design of the detail parts of steam engines and Vol. III their general assembly, and an excellent presentation of all existing types of governors and valve gears with their calculation data and diagrams.

Vol. IV is probably the most important part of this entire work. It contains the test results and experimental data without which the designing engineer could not produce efficient engines, and without which the student could not understand the practical application of the theory to actual design. It permits the designing of steam engines entirely on the results of actual tests instead of having to use empirical formulas or rules. Of especial interest are the numerous entropy diagrams representing the results of steam-engine tests. The usual pressure-volume diagrams do not give as clear a picture of the actual working steam cycle as do the entropy diagrams as presented in this work; because in the pressure-volume diagram the third function—temperature—cannot be directly obtained, whereas the entropy diagram shows clearly all three functions. In the entropy diagram the influence of superheat, the region of saturation, and the influence of repeated reheating or superheating are shown much more clearly, and above all, it gives the engineer a much better basis of comparison when evaluating the results of tests. Another excellent feature is the presentation of these test results on a common basis, referring them to a kilogram of inlet steam, so that the various results obtained can be immediately and correctly compared without having to perform the usual laborious calculations to secure such direct comparisons.

By far the largest number of steam-engine tests available today are acceptance tests in which there is usually an attempt to secure a low water rate for a specific performance under the most favorable load and speed, but which is rarely obtained under the general operating conditions in practice. Such test results are not the best for designing purposes. For instance, in the use of superheat, every useless addition of heat is not taken into account in the desire to show as low a water rate as possible. In collecting these test results—more than 500 are given—and not only in evaluating them properly but also in analyzing them carefully, engineers now have a more solid foundation on which to base their designs and on which further progress in the steam-engine art is made possible. No book on steam engines has ever presented such a careful analysis of test results.

[1] Consulting Engineer, New York. Mem. A.S.M.E.

Too much praise cannot be given Dr. Gutermuth and his collaborator Professor Watzinger for the excellence of this gigantic task said to have taken ten years of labor. No single work on any of the important subjects of technology can show such a complete presentation as does this work on the steam engine. It gives the fundamental theory, the complete details of the mechanisms, the important kinematics and dynamics of the art, and especially a complete analysis of the economics obtained in practice.

The publisher, Julius Springer, also deserves the thanks of the engineering world for having undertaken such a publication, for it must have been obvious that neither author nor publisher could have hoped to obtain a return even of the costs of producing this work, a profit from the sales of such a work being entirely out of the question. In spite of this they have spared no expense to produce a model of excellent printing and illustrating. The illustrations especially can serve as a goal of achievement for all publishers of technical books. No American publisher ever approached such excellence in books of this kind.

After the reviewer has studied this work in the most careful manner, requiring many hours of diligent reading of a subject with which he is rather well acquainted, and of which he therefore could fully appreciate the excellence of both the subject matter and its presentation, he asked himself what has been omitted and what are its shortcomings?

From an American point of view we miss some of the excellent designs of American practice, but this is easily understandable as so many good European designs are given. The work however would have been more complete if more American designs had been included. Although marine engines are touched upon, a fuller presentation of this most important branch of large-steam-engine practice would have been desirable, especially as there is just now a renewed activity in the further development of the large marine steam engine. The steam engine for locomotive drive is also only briefly treated and its present development deserves a better and fuller presentation. The steam-engine development in mining and rolling-mill work is another branch worthy of more elaboration. All these special types of steam engines just mentioned have certain designs peculiar to themselves, and should have been dealt with more fully in this work. The most striking short-coming however is the treatment of the high-speed moderate-size steam engine. The immediate future holds great promise for such types, and there are many special problems pertaining to the design of such units. For instance, without going into this question in any detail, the theory and calculation of rotational oscillations or torsional vibrations of the crankshaft of high-speed engines is a very important and real problem today.

Who will use this work? Surely not the technical schools as a text book; the price is prohibitive, and the field is covered too exhaustively for any student's use. The designer of the steam engine surely will use it; the entire work is the best reference book he can consult. Engineers not intimately connected with the steam-engine development will find the book too voluminous, but will use it as a reference work when looking up any special problems. Other scientists interested in the progress of technology need a more condensed work of only one-tenth the size of this work for the survey they are interested in. The large number of semi-technical general managers of power plants, operators, and mechanics will not use it. It will therefore serve only as a reference book in engineering libraries, technical schools, and in the steam-engine designing rooms of industrial plants.

We cannot subscribe to the author's views expressed in his preface to the book where he states that the steam engine stands at the end of its development. To the contrary, the development of the steam engine for large powers is just beginning.

Committee on Heat Transmission, National Research Council, Reports Progress

AT THE instance of the National Research Council a committee was formed several years ago whose function was to coordinate and classify research activities in the field of heat transmission. This Committee was subsequently reorganized with W. H. Carrier as chairman and sufficient funds were donated by various industrial concerns and public utilities to finance its activities for a three-year period. W. V. A. Kemp, formerly research engineer of the American Engineering Company, was appointed director of the activities of the committee.

The language of the science of heat transmission has long been in a highly chaotic state, each worker in the field having used whatever definitions and symbols occurred to him as being convenient. To correct this condition, the Committee on Heat Transmission has appointed a sub-committee on definitions and nomenclature, headed by Dr. E. F. Mueller, of the Bureau of Standards. This sub-committee has submitted its report, which is a clear, concise statement of the definitions, fundamental equations, and symbols to be used in the science of heat transmission. This report will be submitted to the American Engineering Standards Committee for acceptance, and subsequently given widespread publicity in the scientific press, with the hope that all future work in the field may be guided by, and based on, the recommendations contain therein.

For a long time industry has demanded standardized methods and procedure for testing solid thermal insulation. Sub-committees have been formed to draw up such methods, procedure, and recommended apparatus.

A survey of active research work in progress on heat transmission in the educational institutions of this country has been completed. A report for publication is now in preparation. A similar survey is also being conducted throughout the larger industries of this country.

The primary object of both reports has been (1) to provide all those engaged in work in heat transmission with information as to where similar work is being prosecuted and, (2) to attempt to aid in the solution of industrial problems in heat transmission by instigation and fostering research on such problems in the above-mentioned educational institutions, in governmental bureaus, and elsewhere. This latter object has been attained in several cases, where an individual industrial concern is directing and aiding the research staff of an educational institution in the solution of a problem in heat transmission of general interest.

One of the most important reasons for the formation and continued existence of the committee on heat transmission has been the collection and dissemination of authentic information on this science. To that end, the Committee has undertaken to sponsor both scientifically and financially the preparation and publication of two critical texts on heat transfer. One will be written by Prof. W. H. McAdams of Massachusetts Institute of Technology and will deal with the promotion of heat transmission, such as in boilers, heat exchangers, oil stills, condensers, and similar apparatus. The other text will deal with the retardation of heat flow in all its aspects, such as high temperature, steam, low temperature, and building insulation and will be written by L. B. McMillan, chief engineer of the Johns-Manville Corporation.

Each of these texts will receive the benefit of the advice and criticism of the sub-committees of which these gentlemen are the respective chairmen, and the completed work will represent a consensus of opinion of the highest authorities in this country in the science of heat transmission.

Synopses of A.S.M.E. Transactions Papers

THE papers abstracted on this and following page appear in the Railroad section of A.S.M.E. Transactions as published in its new form. This section has been sent to all who registered in the Railroad Division. Other sections are in the course of preparation and will be announced, when completed, in later issues of "Mechanical Engineering."

RAILROAD PAPERS

Progress in Railroad Mechanical Engineering

THIS report of the Railroad Division shows that progress in railway mechanical engineering has been steadily toward bettering the operating efficiency of railroads by continuing the effort to increase the gross ton-miles per freight-train-hour. This unit is becoming generally recognized as a most valuable index. Part of the accomplishment is due to heavier and more efficient motive power, part to improvements in signaling, heavier car loading, etc. The report discusses such matters as motive power, economics, rolling stock, technical training and education, and trends in development. An extensive bibliography is included. [Paper No. RR-50-1]

The Mechanical Engineer in the Railroad and Railroad-Supply Industries

THIS is a report of the Sub-Committee on Professional Service of the Railroad Division and is intended to guide those who desire to enter the railroad or railway-supplies industries and those who must advise young men in the choice of a career.

Much of the information contained in this report was obtained by studying and analyzing the careers of railroad and railroad-supply officers, published in the railway trade press. This was also supplemented by writing direct to the various companies for additional information. The Sub-Committee on Professional Service has assumed from the beginning of its work on this project that what the young mechanical engineer wants and should have are facts, not advice. He ought to have a fairly accurate picture of the industry he expects to work in before he enters it. Such a picture is not difficult to obtain if one takes the time to assemble and study the facts. A study of the careers of railroad and railroad-supply officers has been made in preparing this report, and it will reveal many essential facts.

Appendixes give a list of officers in charge of railway apprentices and railway-supply company officers to whom students may write for information regarding employment and an outline of the training courses which are offered by various railroads and supply companies. [Paper No. RR-50-2]

Can Accident Prevention Be Reduced to a Science?

By THOMAS H. CARROW

Superintendent of Safety, The Pennsylvania Railroad Co., Philadelphia, Pa.

THE author concludes that accident prevention can be reduced to a science. This conclusion is based on an analysis of the causes of accidents, which shows that not more than ten per cent are due to misadventure and therefore unpreventable, and an analysis of the human factor to which eighty-five per cent of all accidents are attributable. He stresses the need of complete accident records and of educating supervisory responsibility in safety. [Paper No. RR-50-3]

High Steam Pressures in Locomotive Cylinders

By LAWFORD H. FRY

Metallurgical Engineer, Standard Steel Works Co., Burnham, Pa.

IN THIS paper the author attempts an extended survey of the efficiencies obtainable with various steam pressures, and examines the effect of the ratio of expansion on the efficiency. The Rankine cycle, it is pointed out, does not offer a satisfactory basis of comparison for the locomotive; therefore a modification is suggested, known throughout the paper as the "locomotive cycle," and all calculations of the paper are based on this cycle. Changes in boilers to permit operation at high pressures and temperatures are discussed, and it is pointed out that such a boiler would probably require some form of water-tube firebox. Detailed computations and comparisons of theoretical indicator diagrams are made, and the "locomotive cycle" is applied to various admission and release pressures. It is concluded that it is possible to secure a considerable increase in the thermal efficiency of the cylinders by increasing the boiler pressure. The use of three cylinders, one operating on high pressure and two on low, makes compounding a very simple matter, permitting the greatest return to be received from the high pressures. For the present, however, it is not felt to be expedient to use boiler pressures much in excess of 450 lb. per sq. in. gage. [Paper No. RR-50-4]

Back Pressure and Cut-Off Adjustment for The Locomotive

By THOS. C. McBRIDE

Consulting Engineer, Locomotive Feedwater Heater Dept., Worthington Pump & Mchy. Corp., Philadelphia, Pa.

THIS subject is discussed from the operating standpoint only. The author presents data showing the indicated horsepower, the steam consumed, and the dry coal fired as functions of the back pressure. He points out that for each locomotive there is a certain back pressure at which maximum power can be obtained at the lowest cost. He advocates a method to determine the best back pressure experimentally, and the use of back-pressure gages for the guidance of the locomotive engineers. [Paper No. RR-50-5]

Heating and Ventilating of Passenger Cars

By EDWARD A. RUSSELL

Engineer of Design, Vapor Car Heating Co., Chicago, Ill.

AFTER a general discussion of the problem of heating and ventilating passenger cars and a statement of car-heating requirements, the author describes the locomotive equipment, the

connections between cars, and the car equipment of an automatically controlled vapor system of heating. [Paper No. RR-50-6]

The Motor Truck and L.C.L. Freight

By F. J. SCARR

Scarr Transportation Service, Consulting Engineers, New York, N. Y.

THE railroads are economically best suited for the wholesale movement of freight. The controlling factor in their operation is terminal capacity, and terminal costs and delays are the chief obstacles to their greater participation in the short-haul movement of less-than-carload traffic.

Under the present methods and conditions, the highway operator can move most less-than-carload freight for considerable distances cheaper than the railways. He will continue to maintain an economic advantage for the shorter terminal hauls, but a new instrument of freight transportation, the unit freight container, will permit the profitable rail handling of much of the traffic now trucked greater distances. This will necessarily result in the restoration of this traffic to the railways.

The container will use both the highway vehicle and the railroad in the portions of the total movement for which they are best fitted. The rail cost of less than one cent per ton-mile—or about one-seventh of the cost of movement by motor truck—will apply to the road-haul portion, and the terminal cost will be decreased because of the elimination of at least four man-handlings of the freight. [Paper No. RR-50-7]

High Steam Pressure and Condensing Exhaust for Locomotives

By JAMES M. TAGGART

Consulting Engineer, New York, N. Y.

THIS paper first discusses present progress in high steam pressure and condensing exhaust for locomotives, and then investigates the theoretical cycles of operations under such conditions. This is followed by a consideration of auxiliary requirements and machine transmission and thermal efficiencies.

In order to confine the treatment within reasonable limits, general arrangements and types of designs have been taken as a basis for the theoretical treatment. These are listed below.

Boilers—water-tube, preferably non-water-line, constant-temperature type
Economizers and superheaters—to form a part of the boilers
Furnaces equipped for pulverized- or liquid-fuel burning
Air preheaters
Forced- and induced-draft fans
Auxiliaries—motor driven in most cases
Feedwater heating
Condenser—probably of the air-evaporated-cooled type
Main drive arrangement—either
1 Turbine with gear transmission
2 Turbo-generator-motor drive
3 Engine, uniflow, multiple expansion direct
4 High-pressure engine direct and low-pressure turbo-generator motor

In no case is there an extension of effects beyond a possible economic practice. [Paper No. RR-50-8]

Vibration of Bridges

By S. TIMOSHENKO

Engineering Mechanics Department, University of Michigan, Ann Arbor, Mich.

IT IS well known that a rolling load produces in a bridge or in a girder a greater deflection and hence greater stresses than the same load acting statically. This "impact effect" of live loads on bridges is of great practical importance. In this paper the following kinds of impact are analyzed:

1 "Live-load effect" of a smoothly running load

2 "Impact effect of balance weights" of locomotive driving wheels

3 "Impact effect due to irregularities." These irregularities include irregularities in the track and also flat spots on wheels.

It is shown that the "live-load effect" of a smoothly running load is small and can always be neglected. The "impact effect of balance-weights" may be of considerable importance, especially under conditions of resonance, and is most severe on bridges of the shortest span which will allow resonance conditions to occur. For the assumptions made in this paper the minimum length of the span to allow such resonance will be about 100 ft.

The "impact effect due to irregularities" of track may attain considerable magnitude in the case of short girders and rail bearers. By removing such discontinuities in the track as rail joints a considerable decrease in impact stresses produced in bridge parts directly subjected to the dynamical effect of moving wheels can usually be accomplished. [Paper No. RR-50-9]

NOTE: Those who have not registered in the A.S.M.E. Railroad Division, whose papers are abstracted on this and previous pages, and who desire copies of any of these papers, may obtain them by using the form given below.

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